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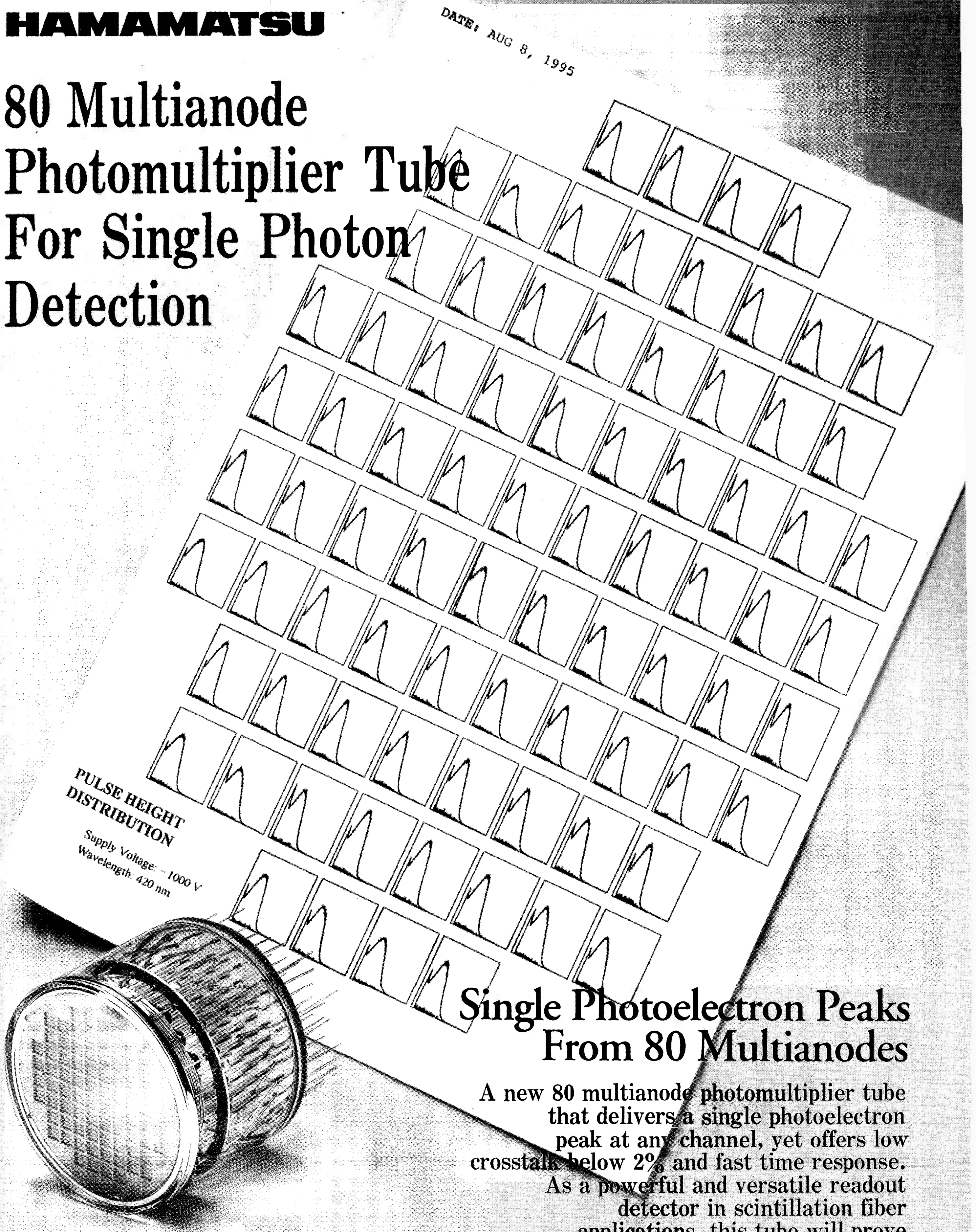

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Around the Laboratories

Physics monitor

LEP to higher energy

At the end of October, equipped with superconducting radiofrequency accelerating cavities, CERN's LEP electron-positron collider operated at a higher collision energy of 130 GeV, en route to a LEP2 physics programme at 160 GeV, the threshold for the production of pairs of W particles, and beyond. Since its commissioning in 1989, LEP had been operating around the Z resonance at 91 GeV. More news in next issue.

Cover photograph: An enthralling acrobatic display was one of the non-physics highlights at this year's Lepton-Photon Symposium held in Beijing in August (Photo W. Kozanecki).

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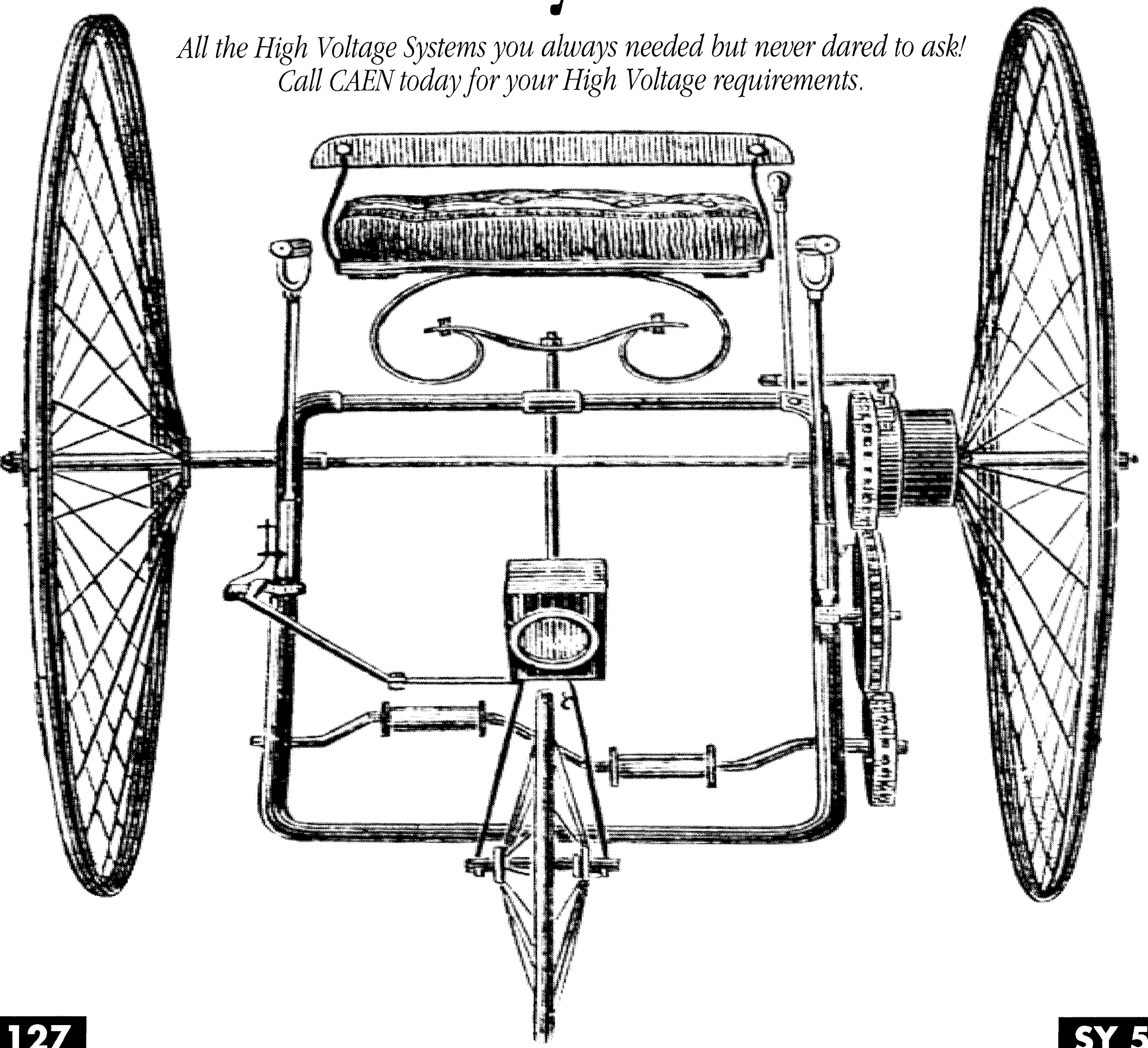

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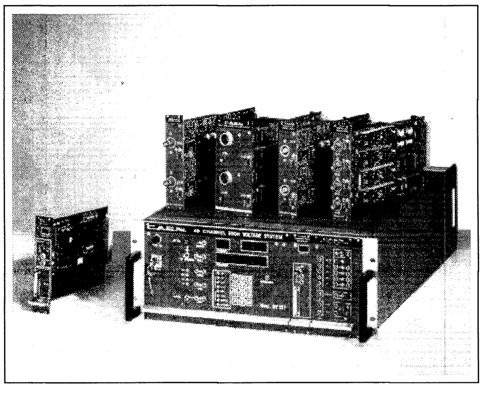

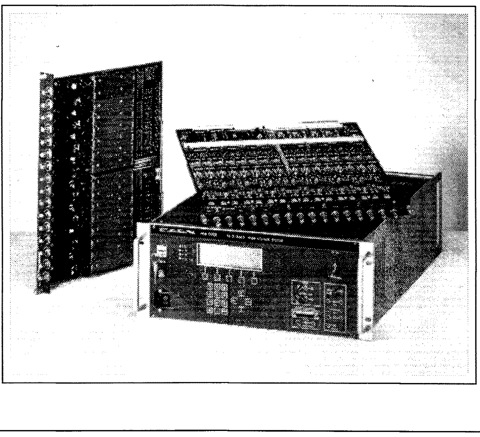

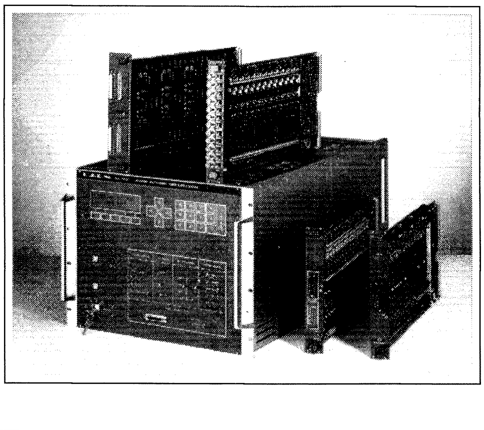

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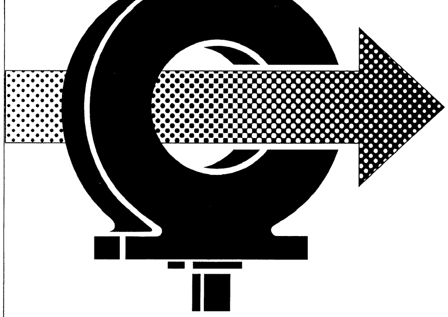

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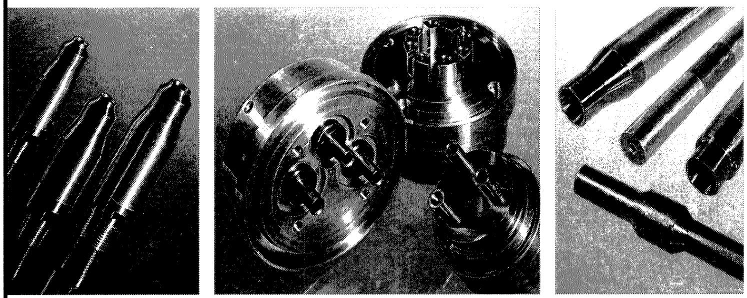

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Around the Laboratories

BROOKHAVEN
Japanese collaboration

The Japanese RIKEN Laboratory is contributing $20 million to help construct the RHIC Relativistic Heavy Ion Collider now being built at Brookhaven and due to be completed in 1999. In return, RIKEN will participate in research at RHIC.

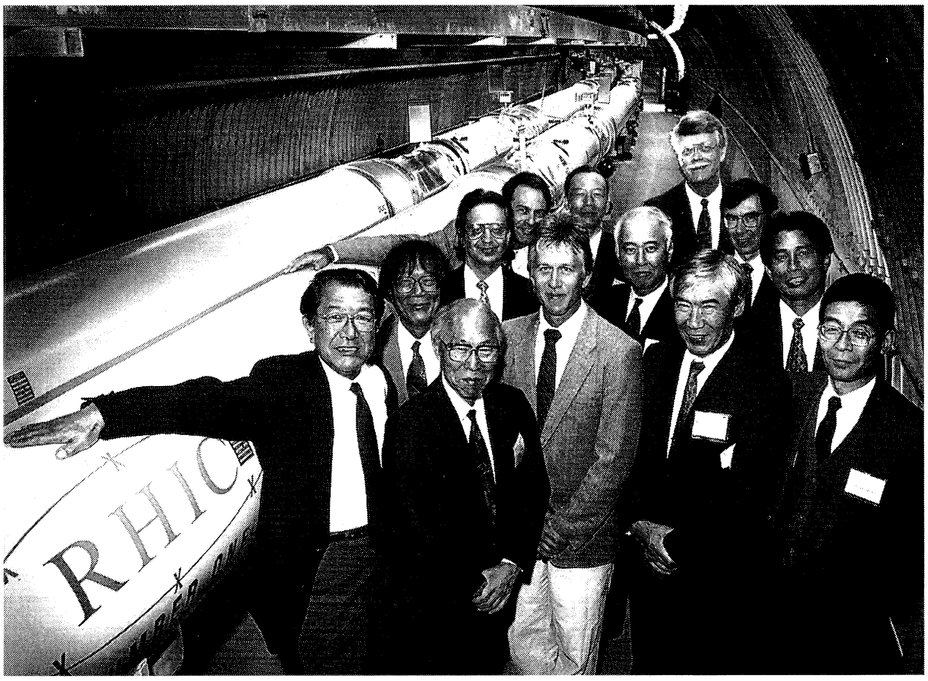
RHIC is being built to collide beams of heavy ions at energies of about 100 GeV per nucleon to explore hot and dense states of nuclear matter, with the ultimate aim of finding the quark-gluon plasma, the medium which existed in the fiery aftermath of the Big Bang before subsequently 'freezing' into nucleons.

However another long-time Brookhaven speciality is handling beams of polarized (spin-oriented) protons in the 30 GeV AGS Alternating Gradient Synchrotron, which will act as the injector for RHIC. With the involvement of RIKEN, the RHIC programme now expands to cover polarized protons.

Half of the RIKEN support will be used to build and install the special hardware needed to handle the polarized beams in RHIC. This includes 'Siberian Snakes' to negotiate depolarizing resonances which would otherwise mar beam acceleration (September 1994, page 27).

The remaining RIKEN funding will go towards additional equipment for the PHENIX detector (May 1992, page 10) to enable it to cover spin physics. This equipment includes a second muon arm, with a magnet and tracking chamber.

A multidisciplinary laboratory, RIKEN - Rikagaku Kenkyusho, or the Institute of Physical and Chemical Research - near Tokyo is currently the scene of construction of an 8 GeV synchrotron X-ray source.



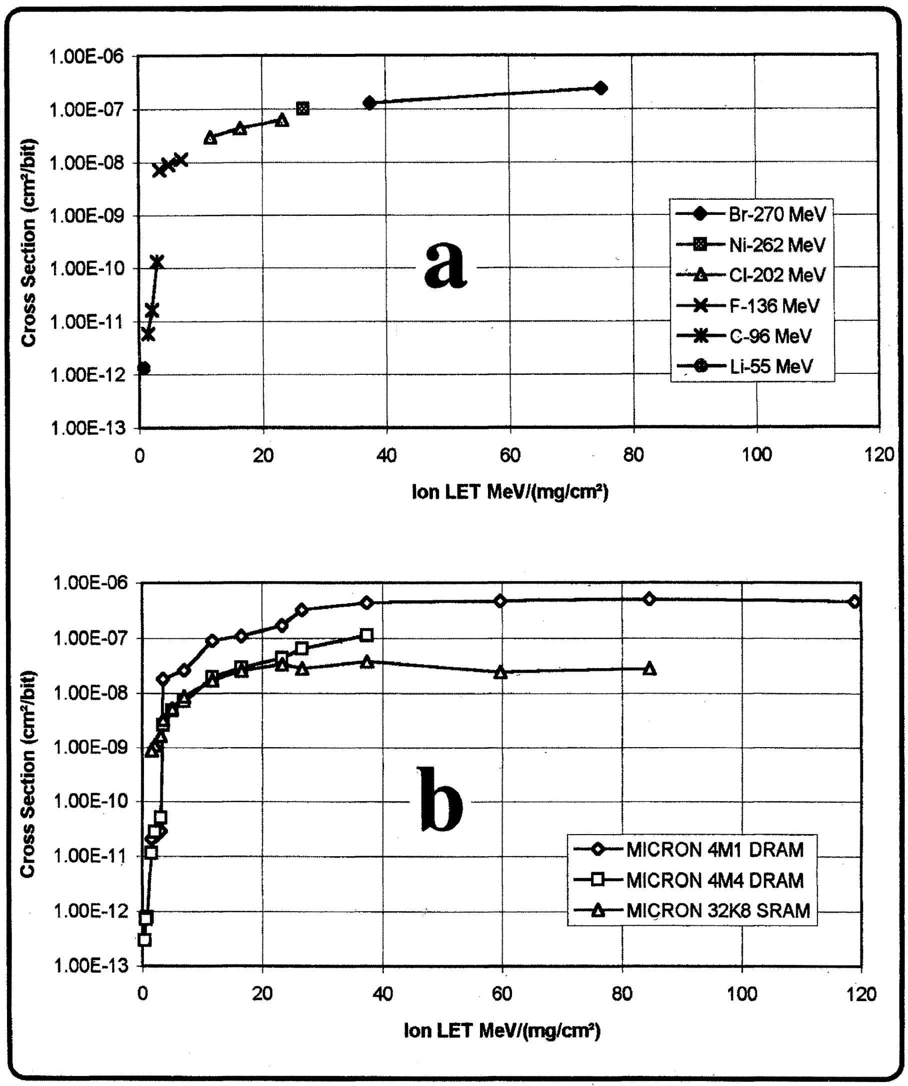
US-Japan collaboration at the RHIC heavy ion collider now being built at Brookhaven. Left to right, front row; RHIC Project Head Satoshi Ozaki, RIKEN President Akito Arima: second row; RIKEN Radaiation Laboratory Chief Scientist Masayasu Ishihara, RHIC Associate Head Michael Harrison, RIKEN Executive Director Hiromichi Kamitsubo, RIKEN Contract Management Division Director Takaaki Hattori: third row; Brookhaven Director Nicholas Samios, RIKEN Planning Office Director Michio Seki, RIKEN International Cooperation Office Director Hideo Yabuki: fourth row; Brookhaven senior physicist and PHENIX Projector Director Samuel Aronson, RIKEN Planning Office Vice-Director Minoru Yanokura, Brookhaven Associate Director Thomas Kirk, and RHIC Associate Head Thomas Ludlam.

Industrial applications in tandem

Because heavy ion injection into Brookhaven's Alternating Gradient Synchrotron (AGS) takes place only during 3-4 months per year and injection to the RHIC heavy ion collider (now under construction) will only take a few hours per day, a large fraction of the time at Brookhaven's Tandem accelerator is available for industrial and technological applications.

These applications, in addition to their intrinsic interest and value, contribute significantly to the operating budget and provide challenges and operational continuity which keep people alert and machines ready to respond. The two main types of applied work are the radiation testing of spacecraft semiconductor components and the production of track-etched plastic filter membranes.

Starting in 1987, a coalition of major US government agencies collaborated with Brookhaven to develop a



Brookhaven has a powerful and user-friendly test facility for investigating space-radiation effects in microelectronic devices. The main type of effects studied are the so-called Single Event Upsets (SEUs) where ionization caused by a single heavy ion produces a bit flip and hence a computer error or a system crash. The figures show Single Event Upset (SEU) data using heavy ions from the Brookhaven Tandem by personnel from the European Space Agency/ESTEC, Noordwijk, the Netherlands, and from the Institut für Datenverarbeitungsanlagen, TU Braunschweig, Germany.

a) SEU variation with linear energy transfer (LET) for a 16-bit Samsung DRAM, one of several candidate memories for integrating a memory of at least 30 Gbits for future ESA earth observation missions. (As well as the beams indicated, many other ion species are available at Brookhaven.)

b) SEU variation with LET for three advanced digital semiconductor devices used in the MARS-94 mass memory unit. (These data were used to estimate the expected in-orbit upset rates for this scientific mission to Mars, to be launched next year and which will reach the vicinity of the Red Planet in 1997.)

powerful and user-friendly test facility for investigating space-radiation effects in microelectronic devices.

The main type of effects studied are the so-called Single Event Upsets (SEUs) where ionization caused by a single heavy ion produces a bit flip and hence a computer error or a system crash. Such events can also lead to destructive latchups and burnouts which must be prevented at almost any cost.

The wide variety of beams available at the Brookhaven Tandem, while lower in energy than the average heavy ions encountered in space, do cover the entire range of specific ionization and of linear energy transfer values (LET), and are therefore well suited for simulating these effects under controlled conditions.

To make this possible, new systems had to be developed to produce uniform beams and to precisely control and monitor ion fluxes ranging from about 100 to about 10,000,000 particles per sq cm per second. This facility has evolved into a highly automated and well interlocked computer controlled system which can be easily operated by first-time users. High beam purity, good beam uniformity and precise dosimetry are provided to a large community of American and European users in support of their space programmes. The figure shows how single-event upsets (SEU) vary with LET in measurements at Brookhaven by European Space Agency personnel.

A well known technique for producing extremely tiny holes in plastic membranes is the track-etch method. Trails of radiation damage are left behind by energetic heavy ions when they traverse thin films. Controlled preferential etching along these radiation-damaged tracks then produces pores which can be as small as 0.015 microns or as "large" as 15 microns, with pore densities ranging from 10^5 to some 10^9 per sq cm.

A privately financed foil irradiation facility designed and installed at the Brookhaven Tandem is now routinely utilized by a company for the production of a wide variety of filter materials. These products are utilized in such diverse applications as ultrapure water production for the semiconductor industry, analytical quality control methods used by the beer and wine industries, experimental

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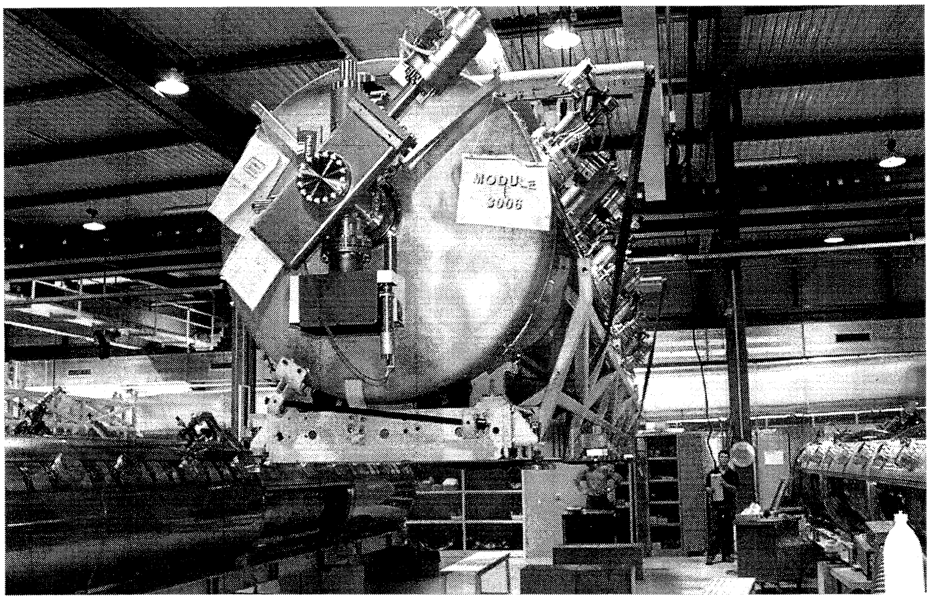
The Brookhaven Tandem is a good example of an accelerator designed for physics research for which additional parallel applications have been developed, to the mutual benefit of both the applications and the original research mission. Success in such endeavours demands recognition of the substantial differences between scientific and industrial requirements, and a considerable investment in time and effort to develop and install the specialized facilities.

Peter Thieberger



A superconducting radiofrequency acceleration cavity for CERN's LEP2 electron-positron collider leaves the preparation area en route to installation in the ring.
(Photo CERN HI28.9.85)

CERN
End of LEP's Z era

A chapter of history at CERN's LEP electron-positron collider closed in October when the four big experiments, Aleph, Delphi, L3 and Opal, logged their final data at the Z energy, just over six years after LEP's first Z was detected. The LEP Z era has been one of great success, both in terms of physics results and the advances which have been made with the machine itself. LEP now takes a step towards becoming LEP2, when the energy is wound up from around 45 GeV to about 70 GeV per beam (September, page 6).

By the end of LEP's 1995 run, each of the four LEP experiments had seen almost five million Zs. Now the spotlight at LEP shifts to producing pairs of W particles, the electrically charged counterparts of the Z.

LEP's first Zs were recorded in August 1989, one month after the machine's first circulating beam. The 30,000 Z decays recorded by each experiment in 1989 confirmed that matter comes in just three distinct families of quarks and leptons.

The values of the Z mass and width quoted in 1990 were 91.161 ± 0.031 GeV and 2.534 ± 0.027 GeV. By the beginning of 1995, these had been fine-tuned to the extraordinary accuracy of 91.1884 ± 0.0022 GeV and 2.4963 ± 0.0032 GeV, and when data from this year's run is included, will be even better. These results, combined with precision data from neutrino experiments and from Fermilab's Tevatron proton-antiproton collider, have put the Standard Model of quarks and leptons through its most gruelling test yet.

Right from the start, collaboration between LEP experiments and the accelerator team has been close, with frequent scheduling meetings determining how the machine is run.

For the first few years, LEP ran on a diet of four bunches of electrons and four of positrons, but by the end of 1992, a way had been found to increase the luminosity by squeezing in more bunches. In 1993, the 'pretzel' scheme (October 1992, page 17), so called because of the shape traced out by the circulating beams, was running with eight bunches per beam, and helped LEP to further tighten the precision of the Z fix.

As new skills were mastered, the 27-kilometre circumference machine became a remarkable precision instrument.1992 saw the LEP beam energy measurement become sensitive to the moon (January 1993, page 4). Later, LEP was found to react to heavy rainfall. These phenomena cause slight movements in the surrounding rock and are amplified by the machine.

In 1995, LEP machine physicists opted for the bunch train approach (September, page 14) to further increase the luminosity. The basic idea was to split each bunch of particles into a string of smaller 'bunchlets' - the bunch train - which holds more particles than the bunch it replaces. In this way, LEP2 will be able to supply the increased event rates needed for W physics.

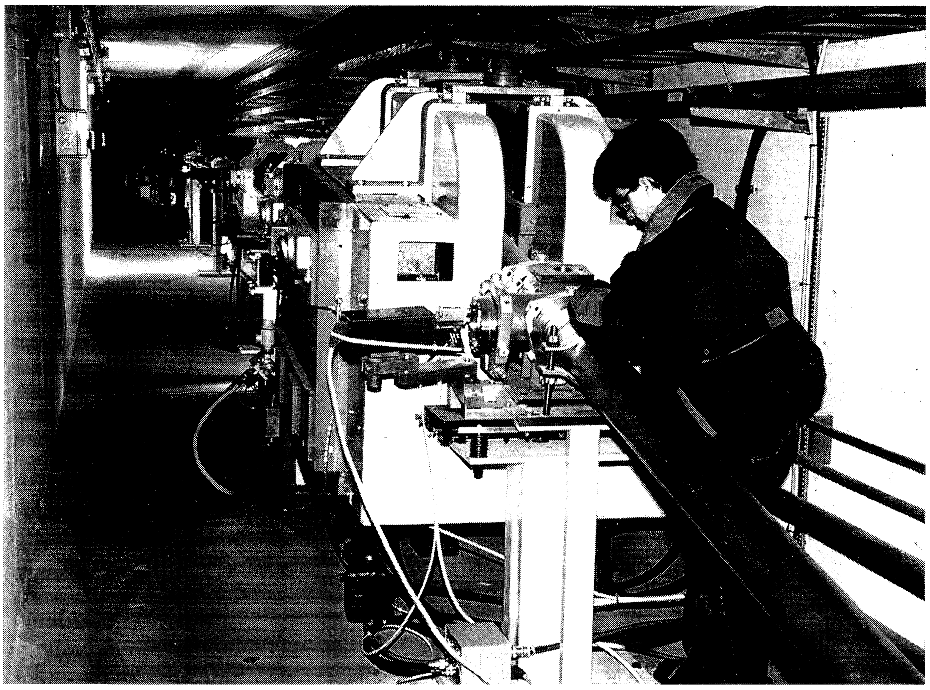
The beamline from CERN's 1 GeV Booster synchrotron which feeds the ISOLDE on-line isotope separator. Catering for a special community, ISOLDE is assured of a bright future, and continues to be a major feature of CERN's diversified research programme. (Photo CERN 40.2.1992)

Diverse portfolio

CERN has always taken a pride in the diversity of its research programme. While the high energy frontier, with its heavy demands for resources, has always provided the main research push, CERN's unique interconnected chain of accelerators naturally provides a broad stage for science. With each machine taking particle beams one step higher in energy to feed the next in the chain, some particles can always be creamed off at each stage for research at an intermediate energy.

Currently, CERN's star attraction is the LEP electron-positron collider. Tuned around the Z resonance since its 1989 commissioning, this machine is soon to be boosted in energy to cover new research aims (September, page 6). Alongside LEP is the impressive programme with heavy ion beams and other fixed-target studies at the SPS proton synchrotron, with two major experimental areas to the West and the North of the site, at the LEAR low energy antiproton ring, at the PS proton synchrotron, and at the ISOLDE isotope separator using beams from the 1 GeV Booster. (For a broad summary of this programme, see the March 1994 issue, page 1).

However the heavy implications of having to commit additional resources for construction of the LHC proton collider mean that other sectors of the research programme will have to be squeezed. Ten years ago, when CERN had to tighten its belt in preparation for LEP construction, the Intersecting Storage Rings (ISR) and BEBC bubble chamber were phased out prematurely in order to liberate resources.



Such decisions are not easy, or even popular. Closure of a productive research tool naturally produces anguish. Under such circumstances, the new possibilities which will be opened up have to be kept firmly in mind.

This summer, a special meeting at the alpine resort of Cogne looked into the crystal ball, to see what research commitments CERN could keep and which could be discarded during the run-up to LHC.

At the SPS proton synchrotron, the Chorus and Nomad neutrino beam studies (November 1991, page 7) have yet to produce initial results and will continue to take data at least until 1997. What happens on the neutrino front after 1997 depends on what Chorus and Nomad will discover. A continuing search for neutrino oscillations after the Chorus and Nomad era would use new neutrino beams based on LHC infrastructure. With these beams, increased sensitivity would come from a larger detector, and possibly from a 'long baseline' experiment, with a detector a long way from the neutrino sources.

Candidates for such distant detectors are the ICARUS liquid argon time projection chamber in the 700 kilometre-distant Italian Gran Sasso underground facility (April 1993, page 15), or the even more distant NESTOR underwater project in the Mediterranean Sea off Greece (November 1993, page 39). Any such distant detector could benefit from a 'short baseline' counterpart mounted on-site at CERN, close to the neutrino source.

Neutrinos apart, the research programme in the SPS West Experimental Area is now mature and reaching a natural conclusion. However fruitful studies of heavy quark spectroscopy based on the Omega detector merit continued effort.

With neutrinos a traditional feature of the SPS West Experimental Area, the North Experimental Area's counterpart muon beam has resulted in important discoveries in the field of nucleon structure. The current muon experiment, the SMC Spin Muon Collaboration, is looking for a successor. This and ongoing spectroscopy requirements could be accommodated in a single spectrometer, provided a strong and committed community can assemble the necessary resources.

Another flagship SPS experiment is the NA48 study of CP violation (March 1992, page 7). The apparatus will be ready soon, and data taking would take several years.

CERN's heavy ion programme received a major boost last year with the arrival of the first beams of lead ions (December 1994, page 15). First physics results are eagerly awaited, and already effects seen by earlier runs using sulphur beams suggest follow-up studies. The plan is to review CERN's heavy ion programme sometime next year in the light of initial results from the lead beam studies.

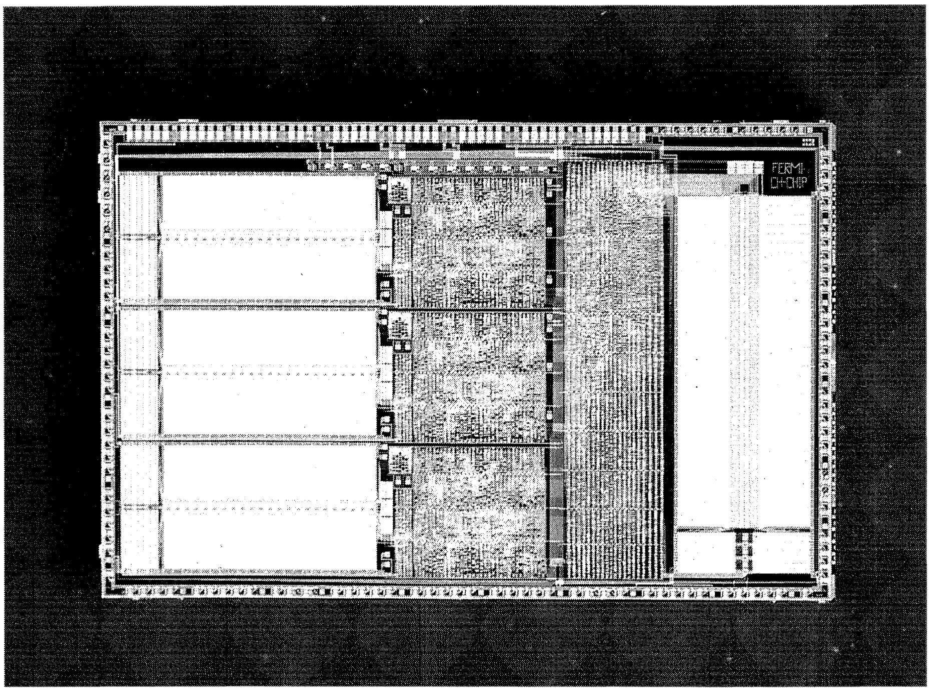
Away from the SPS, at the LEAR low energy antiproton ring some major studies are nearing the end of their initial objectives - notably the CP LEAR experiment providing a valuable new window on CP violation, and the Obelix spectroscopy study. However other experiments, notably the Crystal Barrel, could benefit from continued running. Reluctantly, CERN's Research Board considers that the resources needed for continued LEAR running are not commensurate with the gains, and recommend that LEAR should be closed next year.

However with CERN's pioneer tradition of antiproton physics, it would be a pity if antimatter beams evaporated completely. Studies are underway to seek a cost-effective way of continuing to supply a modest level of antiprotons for experiments on 'trapped' antiparticles..

Also at lower energies, the PS proton synchrotron now carries out valuable studies on neutron spallation for investigations on possible new routes to the exploitation of nuclear energy (April, page 7).

A particular highlight of CERN's research programme the ISOLDE isotope separator. After having been moved from its original home at the now-closed synchrocyclotron, a revamped ISOLDE reappeared in 1992 using beams from the 1 GeV Booster. Catering for a special community, ISOLDE is assured of a bright future. A new pilot experiment on neutron-rich nuclei will greatly enrich the ISOLDE programme and point to new directions for future research.

While CERN's research programme over in the coming years will inevitably be slimmer than at present, it will still be a valuable complement to LHC.



The FERMI (digital Front-End and Readout MIcrosystem) project is developing a novel approach to the construction of readout systems for LHC calorimetric detectors. This is a microphotograph of a 11 x 17 mm FERMI Channel Chip containing one million transistors and including the look-up table and pipeline memory for three channels.

Microelectronics for LHC detector elements

The electronics required to instrument the detectors to be used at CERN's future LHC proton-proton collider represents one of the biggest challenges so far. With proton bunches only 25 nanoseconds apart, the experiments will have minimal time to digest some very complex interactions, with hundreds of secondary particles in each bunch crossing (April, page 4).

Capturing this data from LHC's big high-performance detectors is a real venture for the designers, given the new level of precision, granularity and data rate required by these experiments. In addition, the harsh radiation environment and a certain degree of inaccessibility create new demands for reliability and autonomous running.

An LHC experiment, with its tens of millions of electronics channels, will be impossible to assemble in the classical way with the electronics in crates and racks accessible outside the detector volume. To operate fast enough, a substantial part of the electronics must be placed directly on the detector elements and the data considerably compacted before being transferred to external data acquisition and storage systems. This generates in turn further demands on the electronics in terms of power consumption, fault tolerance and local signal processing power.

Some LHC detectors, notably calorimeters, demand a huge dynamic range of 16–17 bits (10^5) with a resolution of up to 11 bits in order that uncertainties introduced by electronic quantization will not affect the measurements.

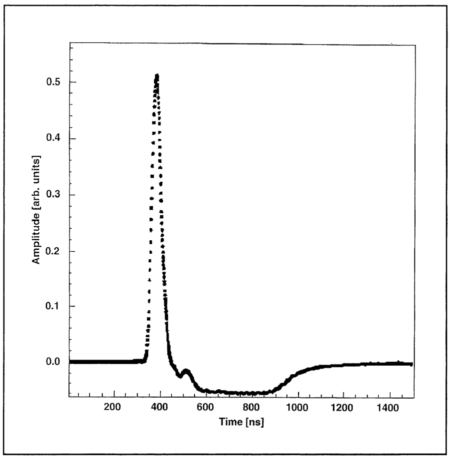
As part of CERN's Detector Research and Development programme (April, page 3), the RD16/FERMI (digital Front-End and Readout MIcrosystem) project is developing a novel approach to the construction of readout systems for LHC calorimetric detectors, integrating directly on the detector most of the acquisition and processing functions using a fully digital approach. It involves a collaboration of nine research institutes in France, Italy, Sweden and Switzerland, together with three high-technology industrial firms.

FERMI's aims are achieved using microsystems, with a higher level of integration combining, in a modular architecture, a number of functional blocks in the form of high-speed applications-specific integrated circuits (ASICs). Recent developments in the domain of multi-chip-modules allow all the functional blocks required for the acquisition and processing of very high dynamic range data, including the extraction of trigger information and local data reduction, for a number of channels to be integrated on a single silicon substrate. The current FERMI prototype microsystem contains almost 4×10^6 transistors on a 5x5 cm substrate, comparable to a Digital Equipment Alpha CPU chip.

FERMI is based on early digitization of compressed analog information from the detector, absolute data correction through look-up tables, and digital signal processing for the feature extraction, both for trigger and readout. Modern data processing techniques and high level integration allow, for the first time, absolute calibration to be achieved in parallel for each channel at the detector level, and in real time.

In 1991, when the FERMI project was started, adequate analog to digital converters (ADCs) did not exist. With the LHC requirements in view, an R&D programme aimed at producing, as a first step, a 10–bit 70 megasample(MS)/s converter with minimal power consumption. Two approaches were pursued, a "Two-Step" and a "Parallel Successive Approximation" converter. The latter, patented, is now operational and must be considered as one of the best A/D converters available today. Key parameters at 40 MS/s (the LHC bunch crossing rate) are: Resolution 10 bits; Differential non-linearity ±0.7 LSB (least significant bit)/ 0.18 LSB RMS; Power consumption 150 mW (plus that of the reference voltage ladder).

Recent improvements in semiconductor technologies allow even better performances and an ambitious programme aiming at a 12-bit 100 MS/s converter has been initiated as a joint project between FERMI and ETH-Zürich, Switzerland.



Reconstructed waveform from the liquid argon 'Spanish Fan' endcap calorimeter prototype for the ATLAS experiment, showing the excellent imaging properties of the FERMI acquisition chain.

Information from the detector is continuously sampled at high speed (40 or 80 MS/s). To reduce the data volume and, for the trigger functions, to identify the time origin of the signal, extensive Digital Signal Processing (DSP) techniques are applied. Test beam results show that this provides an almost continuous imaging of the input waveform, such that the input signal is completely reconstructed and the relevant parameters are retrieved, even under severe distortions generated by heavy pile-up conditions, as encountered when operating at very high event rates.

For all DSP operations the digital data is linearized and corrected by look-up tables, guaranteeing that the information used for the real-time trigger decisions is identical to the data later used during the analysis. The filter retrieving the final energy information has an intrinsic resolution of 0.07%.

The complexity arising from moving such massive processing power onto the detector itself led FERMI to adopt modern fault tolerance techniques, such as those currently applied in spaceborne applications, in order to maintain, and even improve, reliability. Only error detection and recovery, functional redundancy (spare capacity) and some level of programmable reconfigurability in situ - together with radiation-hard ASIC technologies - can guarantee system survival under extreme operating conditions.

The requirements of large-scale reliability and high performance also apply to the assembly and packaging aspects. Wire bonding, as used in standard IC packages, exhibits limited reliability in terms of both mechanical properties and signal integrity for these high-end applications. As a consequence, flip-chip connection techniques have been adopted for final assembly of FERMI microsystems.

Thanks to its inherent modularity and interconnection possibilities, FERMI is being developed for various applications, mainly in the domain of calorimetry and signal imaging for CMS and ATLAS at LHC, as well as for the HERA-B (DESY, Hamburg) and ICARUS (Gran Sasso, Italy) experiments.

VME modules, consisting of the FERMI analog ASIC together with a simplified digital part, and with a dynamic range exceeding 15 bits, have been used in beam tests with detector prototypes from both ATLAS and CMS, with extremely encouraging pulse resolution results.

FERMI is an excellent example of the innovative technology required to face the challenge of the ultra-high interaction rates of 21st-century physics.

SPACE
Major particle physics experiment

NASA and the US Department of Energy (DOE) have signed an agreement to fly a major particle physics experiment on the Space Shuttle in 1998 and later on the international Space Station. Samuel C.C. Ting of MIT will lead the experiment's scientific team.

The DOE-sponsored experiment will look for antimatter originating from outside our galaxy and give hints of the mysterious 'dark matter' - as yet undiscovered material that could make up most of the universe. It extends the repertory of space-borne detection techniques to explore the Universe beyond the stifling blanket of the Earth's atmosphere.

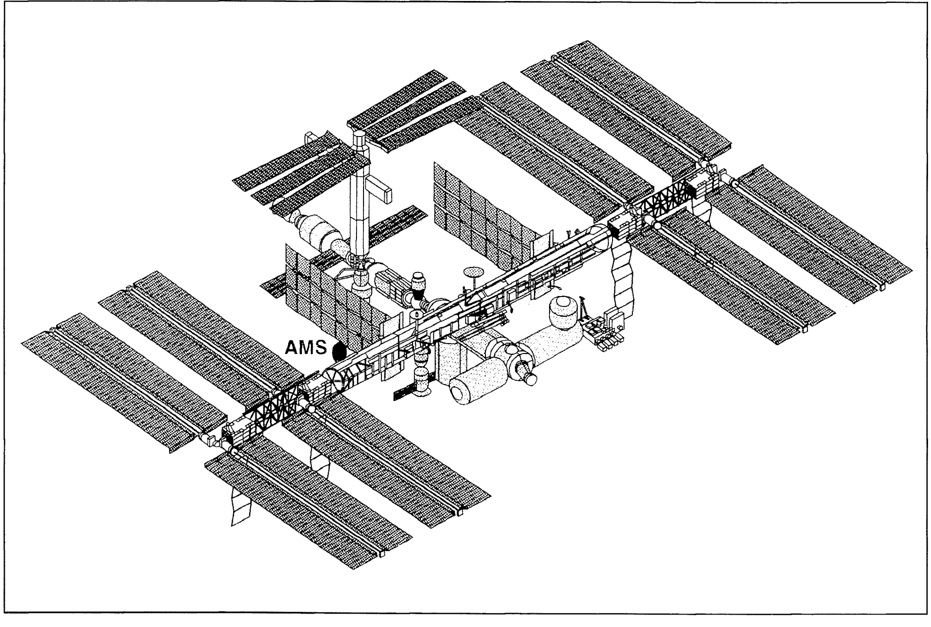
A collaboration of some 37 universities and laboratories in Europe, the US, Russia, China and Taiwan will use the Alpha Magnetic Spectrometer (AMS) - the first large experiment equipped with a magnet ever placed in orbit - to study cosmic particles and nuclei.

Special contributions have come from Bologna, ITEP (Moscow), ETH Zurich, Geneva and Perugia.

Sam Ting, who shared the Nobel Prize in 1976 with Burton Richter for their independent 1974 discoveries of the J/psi particle, currently leads the large L3 experiment at CERN's LEP electron-positron collider. He described plans for the AMS experiment in his summary talk at this year's major international Lepton-Photon Symposium in Beijing.

The 3-tonne AMS magnetic spectrometer will include a solid-state (silicon) tracker measuring to within 10 microns, supplemented by Cherenkov counters and with strip/ scintillator assemblies for triggering.

The detector design ensures that it is as light as possible compatible with its aim of making repeated measurements, while providing a high level of spare capacity (called 'redundancy' by physicists) ensuring that the



Artist's impression of the International Space Station, showing the position of the AMS (Alpha Magnetic Spectrometer) for extraterrestrial particle physics studies.

detector is able to operate unattended in the harsh conditions of outer space. Three levels of triggering are foreseen before passing the data to the on-board computer prior to transmission to earth.

The magnetic material, a special alloy of rare-earth (neodymium), iron and boron, will be supplied by China. Additional space is reserved for a 1-tonne astrophysics detector underneath the magnet for accurate measurements of positrons, antiprotons, nuclei, etc.

A major physics objective is the search for nuclei of antimatter, which will show up as oppositely curved tracks.

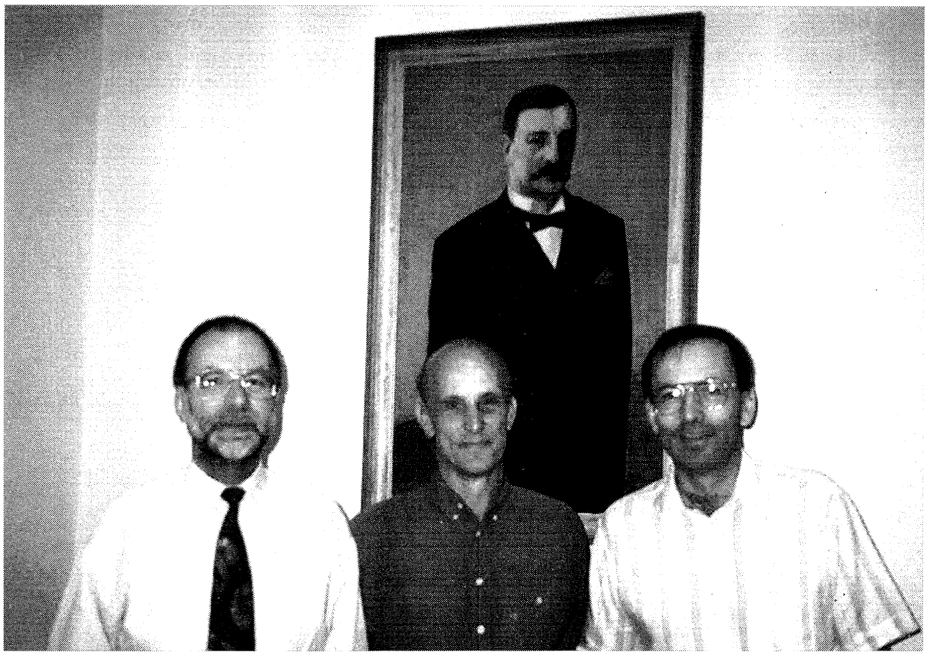
With naturally-occurring antimatter almost unknown in our narrow experience, conventional Big Bang theories naturally incorporate an 'arrow of time' which ensures that antimatter has long been annihilated and that the resultant Universe is composed of matter alone. However on the intergalactic scale, there could be room for a different picture.

The plan is to fly AMS initially as a Space Shuttle payload on the STS-90 mission in April 1998. The detector will operate for approximately 100 hours during this mission. This flight will provide data on background sources and verify performance under actual space flight conditions, as well as testing ground control and data communications. Providing a substantial sample of cosmic antiprotons, positrons and high energy gamma rays, this exposure could already provide interesting new cosmic ray and astrophysics data.

The second space flight is scheduled for Space Shuttle mission STS-110 in 2001 for installation on the international Space Station as an attached payload. The detector will operate for three years before being returned to Earth on the Shuttle. The first element of the international Space Station is scheduled for launching in November 1997.

As well as considerably increasing our understanding of known intergalactic physics, these new windows on cosmic particles in their natural environment could lead to totally unexpected new insights.

In its continual round of CERN Member States the European Committee for Future Accelerators (ECFA) recently visited Sweden, where it met at the University of Lund. Left to right, ECFA Chairman Günter Flügge, Head of Lund Physics Department Bengt Lörstad and ECFA Secretary Denis Linglin pose under the stern gaze of spectroscopy pioneer Johannes Rydberg (1854-1919), who spent his entire career at Lund.



Sweden

In its continual monitoring of physics in its Member States, the European Committee for Future Accelerators (ECFA) recently visited Sweden, where it met at the University of Lund in September.

Physics in Sweden is flourishing, with both a long CERN tradition and excellent prospects for future collaboration. On the experimental side, about 80 researchers, including about 30 graduate students, out of a total of 110 (including 50 graduate students), concentrate on CERN for their work. The main centres of experimental activity are: Chalmers-Göteborg; Lund (particle physics and relativistic heavy ion groups), the Royal Institute of Technology - KTH - Stockholm, the University of Stockholm, and Uppsala. Engineering support staff in particle and high-energy nuclear physics number about 25.

There is a strong Swedish participation (34 researchers from Lund, Stockholm, and Uppsala) in the Delphi experiment at LEP with a full commitment to higher energy running at LEP2, in the CP-LEAR experiment, JETSET studies at the LEAR low energy antiproton ring and in a LEAR hyperon experiment. Sweden is also well represented in CERN's extensive programme of nuclear and heavy ion physics, with 12 researchers active in the heavy ion programme, and a contingent in the SMC muon beam experiment.

The strong Swedish interest in CERN's heavy ion programme was underlined by a special national contribution of 1.5M Swiss francs to the new lead ion injector. At lower energies, there is also good Swedish participation (mainly from the Chalmers Institute) in the Isolde on-line isotope separator. The national physics community has always appreciated CERN's diversified programmes and has greatly benefited as a result.

For the future, there is an important involvement (some 40 physicists) in the ATLAS experiment at CERN's LHC collider. Swedish groups have been active in 11 research and development project for LHC physics.

Sweden's heavy ion activity will continue at the RHIC heavy ion collider being built at Brookhaven and later at the ALICE heavy ion experiment at the LHC. For ALICE, a Nordic collaboration of about 50 experimentalists has been set up, together with a collaboration on related theoretical questions.

In addition to CERN-related research, there are national particle physics activities, but the senior people are in most cases also associated with work at CERN. In medium-energy physics, there is the WASA study at Uppsala's CELSIUS ion cooler ring, with 11 researchers. CERN assisted in the construction of CELSIUS, which uses magnets from the old 'g-2' experiment (which measured the anomalous magnetic moment of the muon and subsequently adapted for the ICE beam cooling experiment).

There is also Swedish participation (5 physicists) in the H1 and HERA-B experiments at the HERA electron-proton collider, DESY, Hamburg.

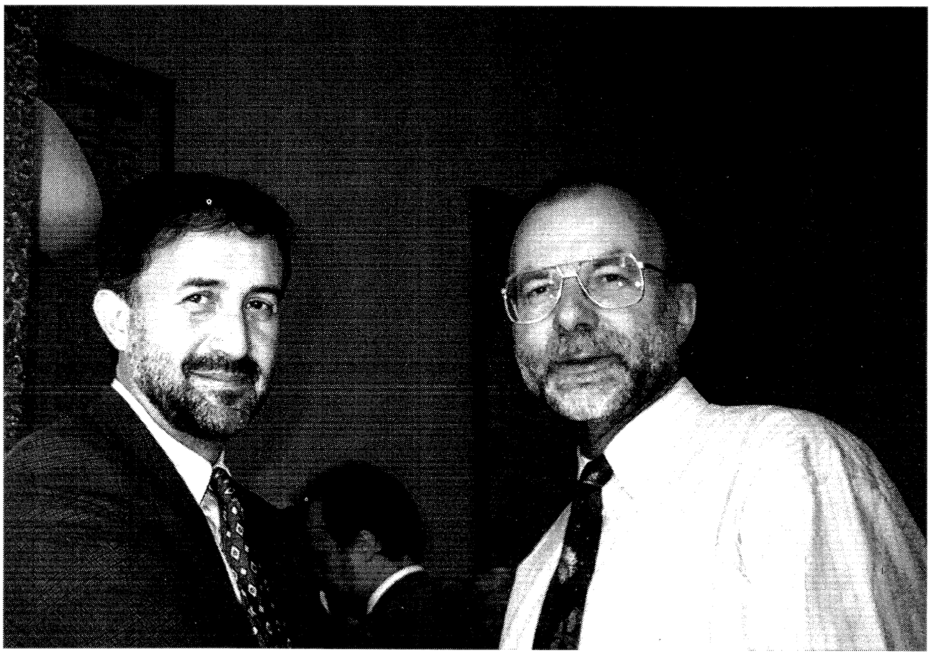
Swedish physicists are active in astroparticle physics projects - the AMANDA neutrino experiment at the South Pole (10 physicists), and the Caprice balloon-borne antimatter experiment.

Accelerator physics is particularly strong in Sweden and activities illustrate how accelerators have become useful tools in other branches of science. As well as Uppsala's CELSIUS storage and cooler ring (mainly used for nuclear and medium energy physics), Stockholm's CRYRING is used for in atomic physics and Lund's MAX rings supply soft synchrotron radiation. A new machine, MAX-2, was inaugurated this year. Sweden also has a dedicated accelerator company, Scanditronix, supplying systems for medical and industrial applications as well as pure research.

On the theoretical side, Sweden counts many well-known figures, 24 of whom are on tenure positions and are interested in CERN physics, together with some 40 graduate students. There are altogether five important theory groups - Göteborg, Lund, Stockholm (2) and Uppsala. Main interests cover field and string theory, phenomenology, model simulation and neural networks. The "Lund model" of particle production in narrow 'jets' is particularly famous.

Sweden is also a traditional partner in Nordita, the Copenhagen theory centre for Nordic physics, which provides a stimulating research setting for young theorists and senior visitors.

It is the Swedish Ministry of Education and Science which pays the Swedish contribution to CERN (of the order of 25M Swiss francs) and provides practically all resources for particle physics research in Sweden, whether through the universities or through specialized funding boards. It covers the material cost of experiments, research and development



ECFA Chairman Günter Flügge (right) of Aachen, and Enrique Fernandez of Barcelona, who takes over as ECFA Chairman next year.

work, half the technical support, positions not covered by the universities (about 20%) and travel. This additional particle physics budget is of the order of 4 M Swiss francs per year. Nuclear physics has its own separate budget.

Prospects appear good. The numbers of high energy experimentalists and theorists are increasing, while former students and young researchers are finding interesting employment in industry.

Research and development work for major new projects, including particle physics, is handled by a new funding source providing strategic long range support to industry. The Swedish-CERN Committee (Chairman Goran Jarlskog) is seeking support for R&D, with fellowships and studentships for improving technology transfer.

For CERN, special funding for ATLAS and ALICE will be available. The present goal is 16M Swiss francs. Funding at the level of 1.2M Swiss francs per year is planned by the Swedish Natural Science Research Council (Naturvetenskapliga Forskningsradet, or NFR), which uses a three-year rolling plan. A significant contribution will also be sought from the Wallenberg Foundation.

Funding for large-scale experimental and computer equipment is channeled through the Swedish Council for Planning and Coordination of Research (Forskingsradsnämden - FRN), under priorities set by the NFR. Basically NFR finances running expenses and plans investment opportunities, which are financed by FRN.

The average amount granted per year for particle physics is at present at the level of 2.5 M Swiss francs. The Swedish contribution to the LEP detectors (DELPHI) was 2.8 M Swiss francs for the period up to 1986, continuing subsequently for infrastructure and for computing hardware.

Two research boards, the Swedish Research Council for Engineering Sciences, TFR, and the Swedish National Board for Industrial and Technical Development, NUTEK, provide funding for applied research in direct collaboration with industry at the level of 0.2 M Swiss francs per year.

A special liaison company (Technotransfer AB) has been set up to promote relations between industry, technical universities and international Research organizations.

Recent noteworthy contributions to arrive at CERN from Sweden include the DELPHI RHIC mirrors and cryogenics for LEP2. Ongoing research and development work covers transition radiation detectors, radiation-hard semiconductor detectors, front-end electronics, and a model LHC magnet. This latter development resulted from a joint Swedish and Finnish initiative with financing provided both by Sweden (NUTEK) and Finland.

Physics monitor

ASTROPHYSICS
The oldest galaxy yet

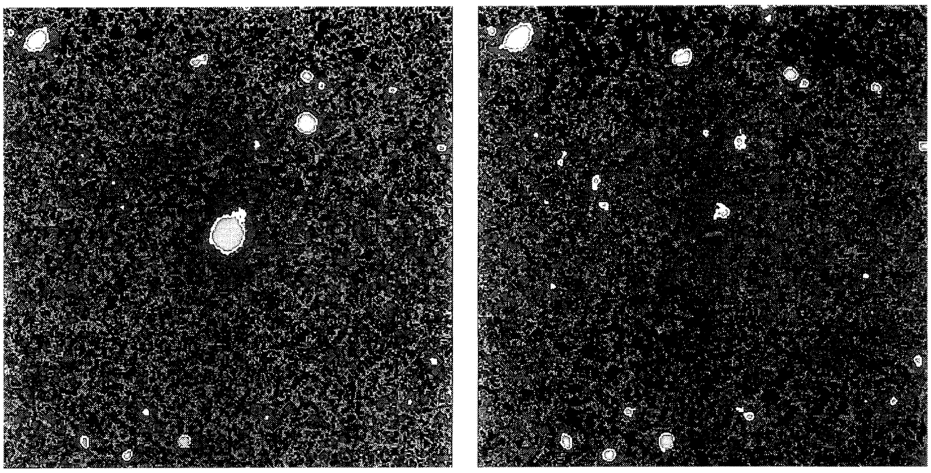
The most remote galaxy ever seen directly has been detected by astronomers using the ESO (European Southern Observatory's) 3.5 metre New Technology Telescope (NTT) at La Silla, Chile, and the 10-metre Keck telescope in Hawaii. It shows that stellar evolution was already well underway some 10 billion years ago, when the Universe was 'only' a few billion years old.

Due to the continual expansion of the Universe in the wake of the Big Bang, visible light emitted a long time ago becomes 'stretched', and appears redder. This 'redshift' is a measure of how long ago the radiation was emitted.

Until this new sighting, the oldest known objects were quasars, huge concentrations of matter at the fringe of the Universe blasting energy out into space. Looking hard at such a quasar, ESO astronomers noticed that light of one particular wavelength was strongly absorbed, indicating an intervening cloud of hydrogen. (In intergalactic space, such absorption spectra are not seen - September, page 34.)

The redshift of the absorption line showed that the cloud itself was almost (90%) as old as the Universe. Further study revealed other absorption lines, showing that the cloud also contained carbon, oxygen, aluminium and sulphur.

So much indirect evidence for stellar-like material suggested that stars might be around. Earlier this year the ESO astronomers embarked on a search for directly visible material. Their CCD SUSI (SUperb Seeing Instrument) picked up a faint signal



The oldest galaxy, as seen by the European Southern Observatory's NTT telescope. The left picture shows the target quasar, with right, the quasar image removed to make the galaxy, situated just to the north-west of the quasar, easier to see.

just 2 arcsec away from the quasar. This tiny angular separation corresponds to a distance 'on the ground' of 40,000 light-years.

There are strong indications that this galaxy contains all the necessary nuclei to produce the observed absorption effects. Only hydrogen and helium were produced in the Big Bang, heavier nuclei having been 'cooked' by thermonuclear reactions inside stars. The newly-observed galaxy is the oldest visible source yet of heavier nuclei.

New state of matter: Bose-Einstein condensation

70 years after work by the Indian physicist Satyendra Nath Bose led Einstein to predict the existence of a new state of matter, the Bose-Einstein condensate has finally been seen. The discovery was made in July by a team from Colorado, and was followed one month later by a second sighting at Rice University at Houston, Texas.

It is Bose's theoretical framework governing the behaviour of the particles we now call bosons which led to Einstein's prediction. Unlike fermions, which obey the Pauli exclusion principle of only one resident particle per allowed quantum state, any number of bosons can pack into an identical quantum state. This led Einstein to suggest that under certain conditions, bosons would lose their individual identities, condensing into a kind of 'superboson'.

This condensate forms when the quantum mechanical waves of neighbouring bosons overlap, hiding the identity of the individual particles. Such a condition is difficult to achieve, since most long-lived bosons are composite particles which tend to interact and stick together before a condensate can emerge. Extremely low temperatures and high densities are required to overcome this problem. As bosons lose energy and cool down, their wavelengths become longer, and they can be packed close enough together to merge into a condensate. Up until now, however, the extreme conditions needed have not been attainable.

Nevertheless, hints of the Bose-Einstein condensate have been inferred in phenomena such as superconductivity and liquid helium superfluidity. Condensates could also play an important role in particle physics and cosmology, explaining, for example, why the pion as a bound quark-antiquark state is so much lighter than the three-quark proton.

A hunt to create a pure Bose-Einstein condensate has been underway for over 15 years, with different groups employing different techniques to cool their bosons. The two recent successes have been achieved by incorporating several techniques. In both cases, the bosons have been atoms. In Colorado, rubidium-87 was used, whilst at Rice University, the condensate was formed from lithium-7. Both teams started with the technique of laser cooling. This works by pointing finely tuned laser beams at the sample such that any atoms moving towards a beam are struck by a photon, which slows them down.

This steadily lowers the temperature to the microkelvin level, still too high for the condensate to form. The next step is to ensnare the sample in a magnetic trap and allow the faster, hotter atoms to escape, a technique known as evaporative cooling. This produces temperatures cold enough for a condensate, but achieving high enough density is still a problem. Conventional magnetic traps leak; there is a point of zero field through which cold atoms can drain away. Both groups used innovative arrangements of magnets to plug the leak.

The Colorado group saw the condensate when they opened up the trap and took a laser snapshot of its contents. They found that the faster atoms quickly flew out, whilst the colder ones, which had undergone condensation, formed a dense central core. From their measurements, they deduce that the conden-

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sate formed at around 20 nanokelvin, the lowest temperature ever achieved, and included around 2000 atoms. The Rice group believes that some 100,000 atoms condensed inside their apparatus, and estimate the temperature at between 100 and 400 nanokelvin.

The condensation of lithium-7 atoms at Rice University is of particular interest for theoreticians, because it was not meant to happen. Unlike rubidium-87 atoms, which gently repel each other due to the residual forces of their orbiting electrons, lithium-7 atoms attract. This led to the prediction that they would form a liquid and drain away long before condensation could occur. The theoreticians will have to revise their ideas, but they can expect some help in the form of new experimental evidence. The Colorado team plans to repeat their experiment, this time using rubidium-85 atoms which also have an attractive residual force.

The observation of the Bose-Einstein condensate opens the door on a whole new world, and physicists are only just beginning to peer through. Apart from the purely esoteric importance of studying the condensate, which offers the opportunity of exploring quantum mechanics in a macroscopic system and gaining new insights into quark physics, the chance to understand better the underlying mechanisms of superconductivity and superfluidity could have wide ranging repercussions.

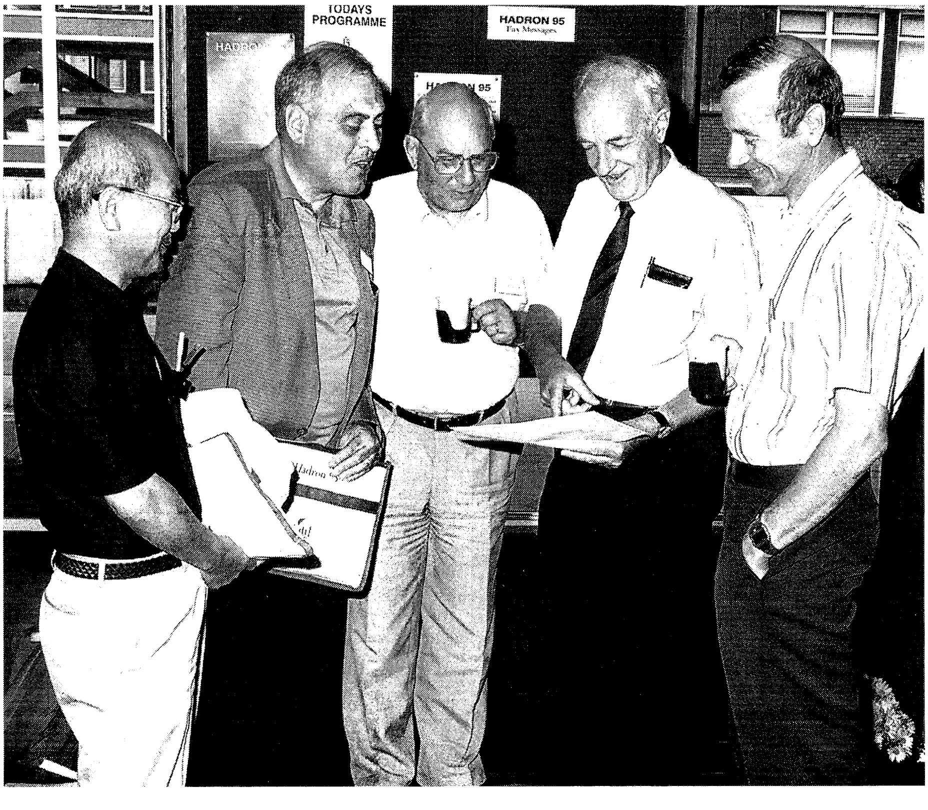
HADRON 95
Looking hard for glueballs

Gluons, the particles which mediate inter-quark forces, should in principle form particles - 'glueballs' - which complement the familiar subnuclear particles built from quarks.

Recent progress in the search for glueballs was a major topic at the 6th International Conference on Hadron Spectroscopy (Hadron 95) held at the University of Manchester. While bound states of gluons are firmly predicted by quark-gluon field theory (quantum chromodynamics - QCD), until recently QCD lattice calculations have been unable to provide reliable predictions of glueball masses and widths, while only tentative and controversial experimental evidence existed.

However studies of gluon-rich processes such as low energy proton-antiproton annihilation, central production in diffractive collisions and radiative J/psi decays have revealed states difficult to accommodate in the conventional quark-antiquark meson classification. Also, the calculations by different lattice QCD groups are now beginning to give consistent results. The recent experimental and theoretical progress presented at the conference prompted Frank Close of the Rutherford Appleton Laboratory to remark "it may be the case that we are at last beginning to see things".

Evidence is now accumulating that the spin-parity 0^{++} glueball has been observed, as the $f_0(1500)$, in a number of different gluon-rich experimental situations. Close argued



In discussion at the 6th International Conference on Hadron Spectroscopy (Hadron 95) at Manchester this summer - left to right - Kunio Takamatsu (Miyazaki), Tullio Bressani (Turin), Hans Bienlein (DESY), Sandy Donnachie (Manchester) and Frank Close (Rutherford Appleton Laboratory).

(Photo Ian Callaghan)

against the widely-held view that meson flavour symmetry - the approximately equal production of strange and non-strange particles - should be expected in glueball decays.

If, as seems likely, the 0^{++} states are close in mass to the conventional 0^{++} mesons, then mixing between the glueball and the quark states would remove the flavour symmetry. He went on to argue that the f_0, with a width of only about 100 MeV, is too narrow to be a quark-antiquark bound state and that its decays have a "gluish" nature.

However the 2^{++} glueballs are expected to be well separated in mass from the corresponding meson nonet and should look very different to conventional mesons.

New results on radiative J/psi decays were presented by Shan Jin on behalf of the BES collaboration at the Beijing electron-positron Collider. In 1984, the Mark III Collaboration at Stanford's SPEAR electron-positron collider reported a narrow state, the xi(2230), decaying into a pair of neutral kaons, although no other decay modes were seen and no other experiment had since been able to confirm it.

Using a sample of 8 million J/psis, the Beijing group now find significant narrow signals in four different channels: charged pion pairs, proton-antiproton, and charged and neutral kaon pairs. All of the signals are compatible with a mass of 2230 MeV and a width of only 20 MeV.

They conclude that the branching ratios into the observed final states are all below 2%, with decay into kaon pairs being as likely as into pion pairs. This flavour symmetry suggests the xi(2230) is of a glueball nature. Although the experiment is unable to determine the spin-parity of this state, lattice QCD calculations give such a mass for the 2^{++} glueball.

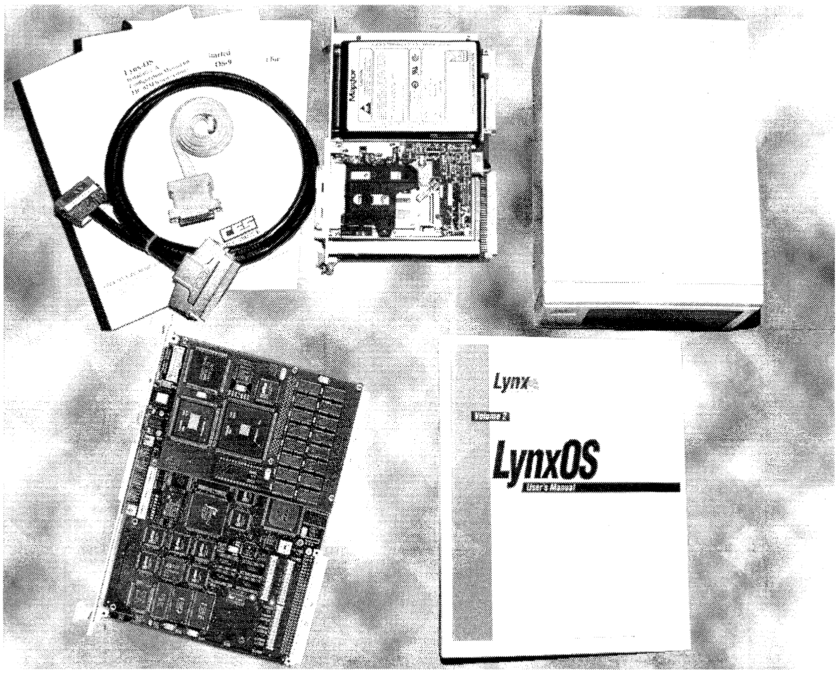
A full plenary session, organized by Hans Bienlein of DESY and Andrew Kirk from CERN, covered future facilities for hadron spectroscopy. The closure of LEAR (see page 5) was seen as a setback to the physics programme. Immediate physics objectives, it was advocated, should include, as an absolute minimum, investigation of the 0^{++}, 2^{++} and 1^{-+} glueballs.

Identifying glueballs needs a full understanding of conventional meson spectroscopy. Spectroscopy of charm will continue with new efforts at Cornell, Fermilab and CERN, while the multiparticle spectrometer at Brookhaven has an ongoing spectroscopy programme. Photon-photon physics at LEP2 could also contribute to the field, while spectroscopy will continue at a number of other facilities, including IHEP/Protvino and DAFNE at Frascati. A tau-charm factory in Beijing (October, page 8) and a possible new facility at CERN for central production experiments (see page 5) were seen as promising future possibilities.

Summarizing, Suh-Urk Chung of Brookhaven and Michael Pennington of Durham stressed that with 99% of strong interaction physics over distance scales larger than 1 fermi, where quarks and gluons are permanently confined in hadrons, continued work is called for, both experimental and theoretical, in hadron spectroscopy. The twin aims of experimental diversity and global data analyses, with as many channels as possible being treated simultaneously, were seen as the keys to further progress.

There was general agreement that much had been learned in recent years, and the 150 delegates left Manchester with the parting thought that, just perhaps, the f_0 will have been positively identified as a glueball by the time of the next conference, scheduled for Brookhaven in 1997.

From George Lafferty



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Books received

Perspectives in Astrophysical Cosmology, by Martin Rees, published by Cambridge University Press, on behalf of the Accademia Nazionale dei Lincei, ISBN 0 521 47530 9 (hbk, £24.95), 0 521 47561 9 (pbk, £9.95).

This small book is based on a series of lectures presented in Milan for physicists and astronomers, covering research at the interface between extragalactic astrophysics, cosmology and particle physics.

Plasma Physics - An introductory course, edited by Richard Dendy, published by Cambridge University Press, ISBN 0 521 43309 6 (hbk £65) 0 521 48452 9 (pbk £24.95)

Now available is the paperback version of this 500-page book, first published in 1993, which uses material from lectures at recent Culham Summer Schools in Plasma Physics. Each chapter is the work of a different author. Beginning with an introduction to the fundamentals, it continues with three themes - phenomena and techniques (turbulence, chaos, computation) with applications in all fields of plasma physics; introductions to research fields where plasma physics is involved; and the physics of fusion plasmas.

From Physics to Metaphysics, by Michael Redhead, published by Cambridge University Press, ISBN 0 521 47405 1 (hbk £19.95)

The author, Professor of History and Philosophy of Science at Cambridge, examines how the latest ideas of physics can be reconciled with ‘down-to-earth’ views of science philosophers. For a Theory of Everything, the physics contender is the superstring picture. As the book is based on lectures given in 1993, it could not benefit from the exciting new Theory of Everything developments (October, page 4)

Introduction to Electroweak Unification - Standard Model from Tree Unitarity, by J. Horejsi, published by World Scientific, ISBN 981 02 1857 5 (£32).

A non-traditional introduction to the theory of electroweak unification.

Smooth Invariant Manifolds and Normal Forms, by I.U. Bronstein and A. Ya. Kopanskii, published by World Scientific, ISBN 981 02 1572X 1 (£51).

Volume 7 in the World Scientific Series on Non-Linear Science.

Bosonization, edited by Michael Stone, published by World Scientific, ISBN 981 02 1847 8 (hbk), 981 02 1848 6 (pbk, £37).
Part 1 (60 pages) is a introduction, Part 2 (470 pages) contains reprints of classic papers.

Spin Phenomena in Particle Interactions, by S.M. Troshin and N.E. Tyurin, published by World Scientific, ISBN 981 02 1692 0 (£42).

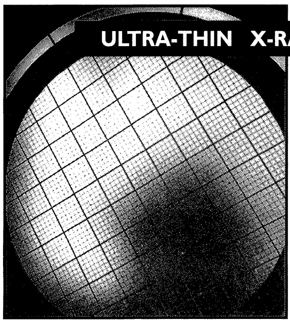
A useful introduction to the formalism and phenomenology of high energy spin processes.

TRIBUTE
Sir Rudolf Peierls
1907 - 1995

With the death of Rudolf Peierls on 19 September the world of physics lost one of its last direct links with the pioneers of quantum theory and a major contributor to its applications. The wider world beyond physics has lost a quiet voice of reason and moderation who passionately believed that, although the genie of the nuclear bomb could not be put back in the bottle, it could by rational discussion and by agreement be kept from wreaking the havoc of which it is capable.

Born in Berlin into an assimilated Jewish family, he attended lectures by Planck, Nernst, Bothe and Sommerfeld. Planck's lectures were “the worst I have ever attended”, Sommerfeld's “a model of clarity”[1]. Thereafter followed a decade travelling among all the major European centres. His first permanent appointment was to the newly created Professorship in Birmingham in 1937.

His most momentous piece of work, which may well have changed the course of history, led to the famous Peierls-Frisch Memorandum to the British Government of 1938 [2]. It concluded that a fission bomb using U235-enriched uranium was feasible, and that, although its immense destructive power “may make it unsuitable as a weapon for use by this country” it would have been disastrous if the Nazis had got the weapon first. It has been described as “[one] of the most remarkable documents in the history of the impact of science on civilization in [its] brevity and clarity and in [its]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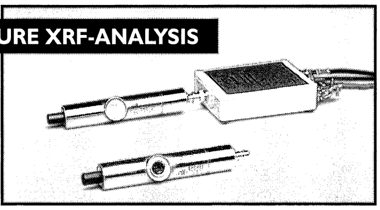

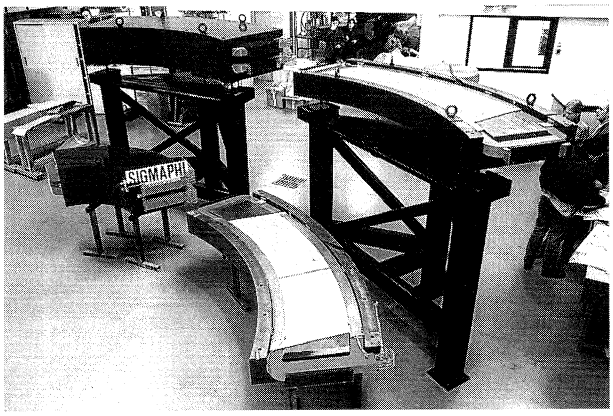
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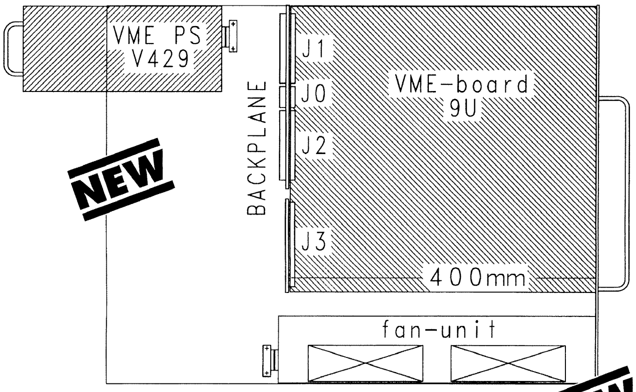
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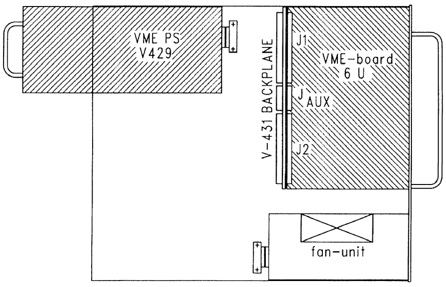
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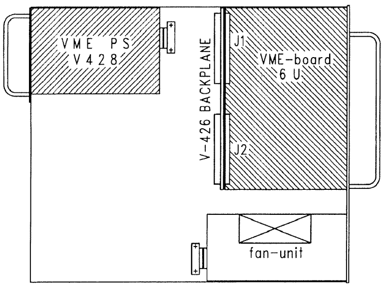
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import". [3]. After his war work, first in Britain then in Los Alamos, he became a leader of the Pugwash movement of scientists dedicated to halting the arms race.

His outstanding basic work includes, in solid state theory, the concept of a "hole", the mechanism for thermal resistivity in insulators, the de Haas-van Alphen effect, light absorption in solids, the "Peierls instability" of the linear chain, the motion of dislocations in a crystal, and phase transitions in the two-dimensional Ising model. In nuclear and elementary particle physics he made many seminal contributions, including the theory of beta-capture, nuclear photo-disintegration, resonance scattering, neutron excitation, collective motion, field quantization, functional methods in quantum field theory, and the concept of an unstable particle as a complex pole. Peierls believed in "strong interactions" between physicists, and attracted interacting participants to his "school" from all over the world. He could reduce a problem to its essence and was a lucid commentator on the current state of the subject. His criticism of ideas he disapproved of could be severe but was always polite.

He strongly believed that the physicists of the world form an extended family. Within that family the many who passed through his Department either in Birmingham or in Oxford, where he moved in 1963, were a particularly close-knit subgroup. He and his Russian-born wife Genia, whom he married in 1931, made a second home for the families of all, retaining a life-long interest in their development and welfare. His was the role of revered father-figure, hers that of kindly yet formidable mother-substitute. Despite the severe blow of Genia's death in 1986, he continued to work, travel and entertain just as they had done together, until his health failed. Even in the last months, his sharpness of mind never left him, and he continued to work on book reviews and on his collected non-scientific papers, and to enjoy the company of visitors.

(This is an abbreviated version of an obituary which appears in the November issue of Physics World.)

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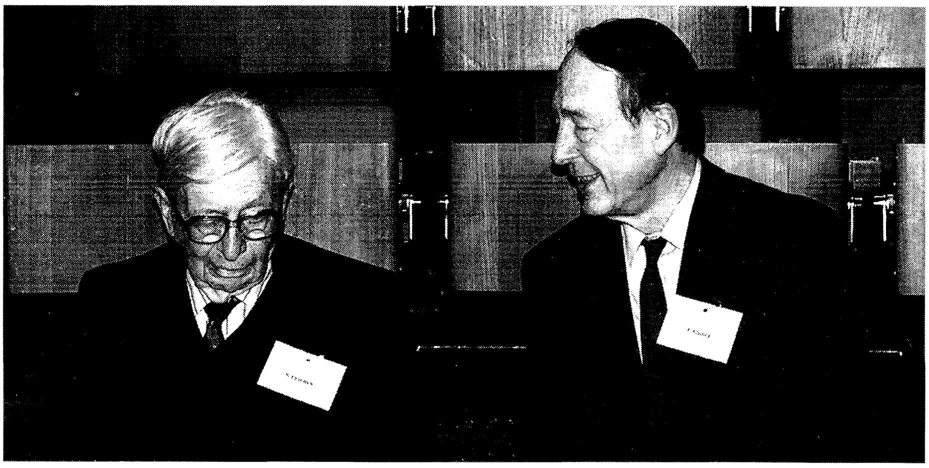
[1] R. E. Peierls, Bird of Passage, Princeton University Press, 1985

[2] Two parts reprinted separately in M. Gowing, Britain and Atomic Energy 1939-1945, Appendix 1, Macmillan, 1964 and R. Clark, Tizard, Methuen, 1965.

[3] R. H. Dalitz and R. B. Stinchcombe, editors, A Breadth of Physics, World Scientific, 1988, p18.



Sir Rudolf Peierls (1909-1995) seen here (left) with Tom Kibble of Imperial College, at CERN in 1991 for a memorial meeting for John Bell.

People and things

CERN Director General Chris Llewellyn Smith (left) and Joseph Lamdan, Israel's representative to the United Nations in Geneva, sign the renewed CERN/Israel five-year cooperation agreement.
(Photo CERN 6.9.1995)

Langevin prize

The prestigious Paul Langevin Prize of the French Physical Society was awarded this year to Costas Kounnas of CERN's Theory Division. A field theorist, Kounnas has always been particularly interested in the application as well as the development of sophisticated theories - quantum chromodynamics and grand unified theories. His work on multidimensional strings and superstrings has enabled such theories to be interpreted in the four dimensions of space-time, thus making predictions possible. After spending several years at Berkeley, he became director of research for theoretical physics at the Ecole Normale Supérieure, Paris, and joined CERN's Theory Division in 1992.

Enrico Fermi memorial unveiled

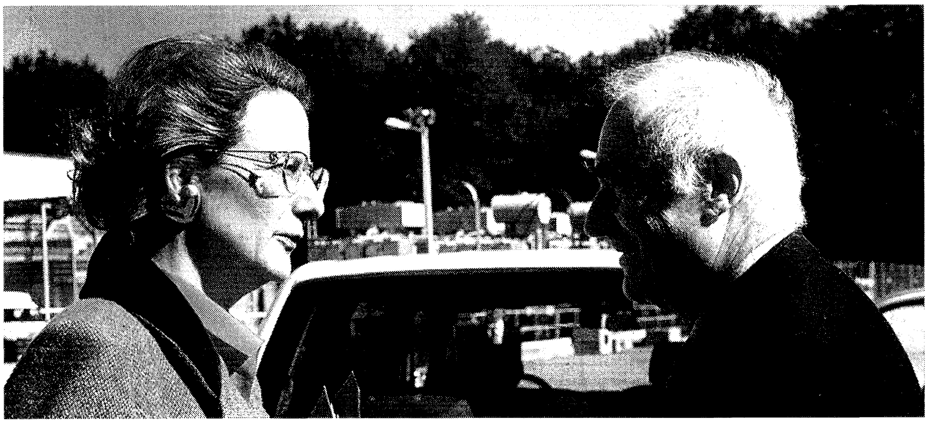
On 11 September in the Church of Santa Croce, Florence, a plaque was unveiled in memory of Enrico Fermi, alongside memorials honouring the greatest Italian personalities in the arts and culture, including Machiavelli, Michaelangelo and Galileo. A bronze plaque by Italian sculptor Corrado Cagli bears the inscription "he gave to the world new strengths and energies", followed by a verse from Dante "Ma misi me per l'alto mare aperto", in recognition of Fermi's steadfast determination in the face of the unknown.

Following a suggestion by Valentino Telegdi, the Accademia Nazionale dei Lincei promoted the initiative to commemorate the great scientist in this "Pantheon of Italian culture". Giorgio Salvini, Minister of University and Scientific Research, Antonio Paolucci, Minister of Cultural Heritage, Mario Primicerio, Mayor of Florence and Sabatino Moscati, President of the Accademia dei Lincei, took part in the ceremony.

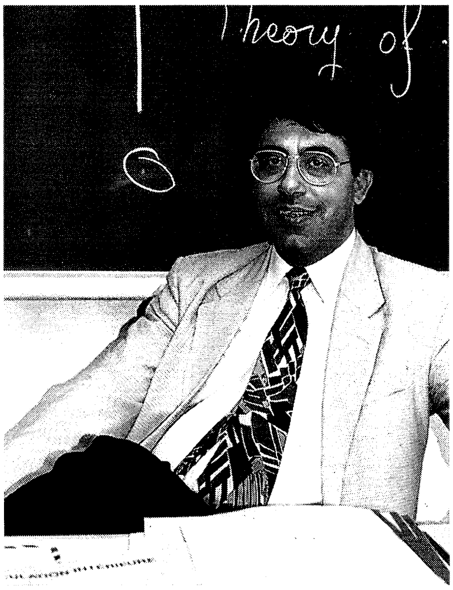
Minato Kawaguti

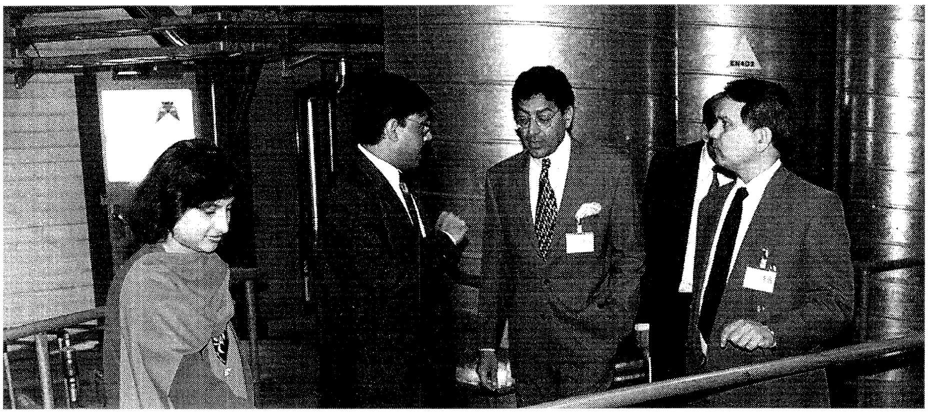
Minato Kawaguti of Fukui University, Japan, and a member of the Atlas collaboration at CERN died on 22 September after an unfortunate

At CERN on 29 September was Elisabeth Dufourcq, French Secretary of State for Research, seen here with CERN Council President Hubert Curien.
(Photo CERN 28.9.95)



Costas Kounnas - Langevin Prize



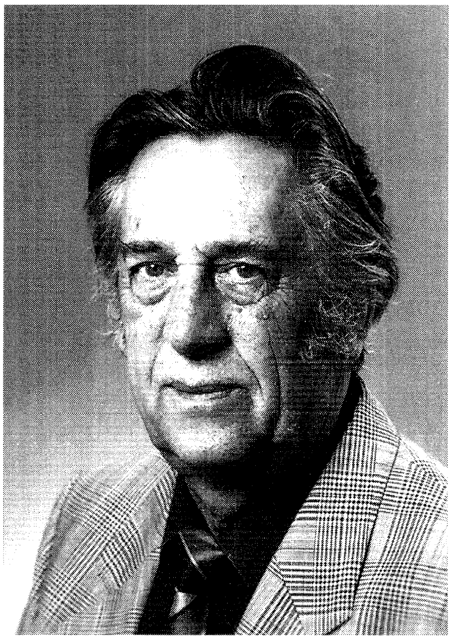


During a visit to CERN on 4 September, Munir Akram, (second from right) Pakistan's Ambassador to the United Nations in Geneva, listens to an explanation by physicist Hafeez Hoorani. Looking on are Minister for Technical Affairs Mohammad Afzal (right) and physicist Mehnaz Hafeez. (Photo CERN HI 5.9.1995)

On 11 September in the Church of Santa Croce, Florence, a plaque was unveiled in memory of Enrico Fermi.

accident in Rio de Janeiro while attended the Computing for High Energy Physics (CHEP) meeting. Struggling with a robber, he fell from a streetcar and succumbed to head injuries.

The Brazilian Minister of Science and Technology issued the following statement: "Following the unfortunate accident of Professor Minato Kawaguti of Fukui University, Japan, I was at once informed by Professor Alberto Santoro of LAFEX/CBPF and I took immediate action to ensure that he received the best possible medical care. I am deeply saddened by his tragic death. I would like to offer my most sincere sympathy to his family and to all his colleagues at Fukui University".



Beat Hahn 1921-1995

Beat Hahn 1921-1995

The death occurred on 22 September of Beat Hahn, innovative Swiss experimentalist who was a member of CERN's Scientific Policy Committee from 1970-72 and a member of the Swiss CERN delegation from 1985-88.

After studies and first research in his native Basel, he moved in 1953 to Stanford to participate in Robert Hofstadter's historic electron scattering experiments. In 1956 he returned to Switzerland, where from Fribourg he helped developed a freon bubble chamber used in experiments at the CERN PS. Always looking for ingenious detector ideas, he was awarded a prize by the American Association of Physics Teachers for his small 'rotation' chamber which relied on tensions in fluids.

After participating in pioneer neutrino studies at CERN, in 1968 he became Professor at Berne, carrying out studies both at CERN and at the Swiss national Paul Scherrer Institute, Villigen. In the early 1980s he was head of the team which developed the tiny BIBC bubble chamber, used at CERN to measure the lifetime of charmed particles, and went on to become a member of the UA2 team at CERN's proton-antiproton collider.

At home in both large collaborations and small groups, Beat Hahn was a gifted inventor and a deceptively modest, unassuming man who nevertheless knew what had to be said or done and never shrank from responsibility.

Meetings

The North-West Europe Nuclear Physics Conference, NWE'96, will be held at the Vrije Universiteit in Amsterdam from 16-19 April 1996. This conference follows that held in Edinburgh in 1992 and is the second in a series organized by the nuclear

(continued on page 27)

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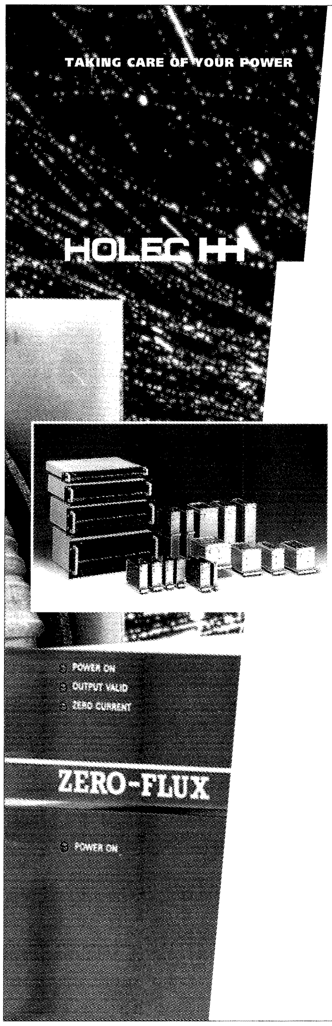

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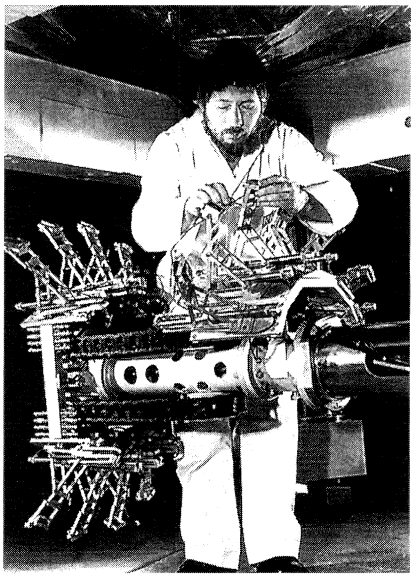

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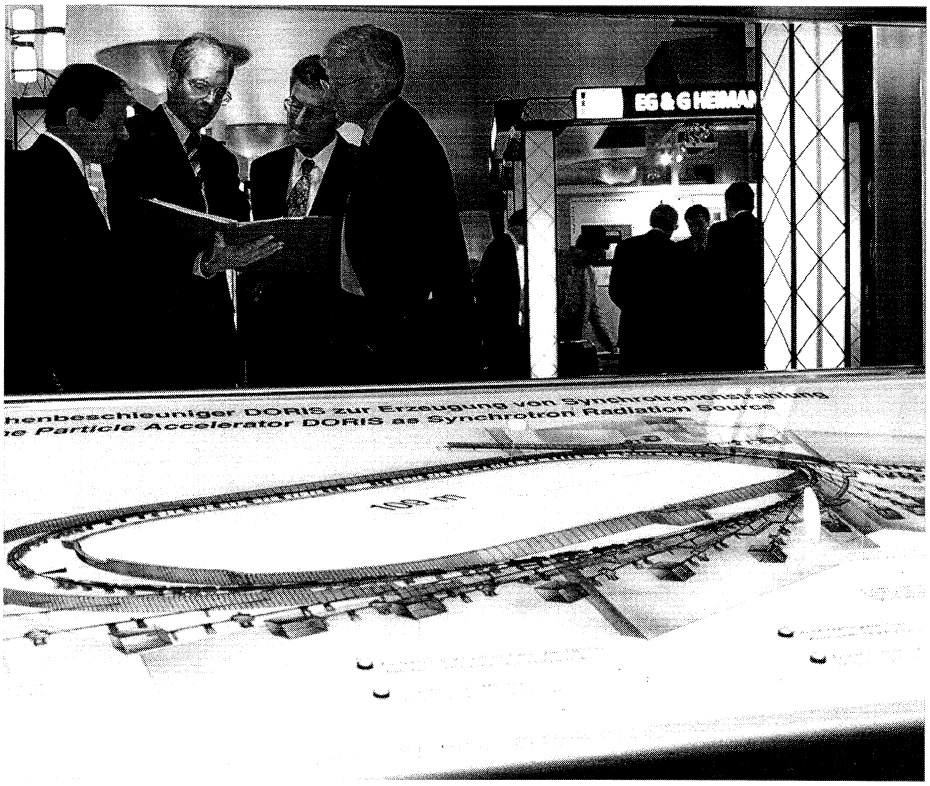
Featuring in the recent very successful 'Germany at CERN' exhibition at CERN were stands representing two major German Laboratories - DESY, Hamburg, and GSI, Darmstadt, whose work is closely related to that of CERN. Below,: at the DESY stand, Jochen Schneider explains the HASYLAB synchrotron radiation facility to (right to left) CERN Director General Chris Llewellyn Smith, Ministerialdirigent Hans C. Eschelbacher, and CERN Research and Technical Director Horst Wenninger.
Right, at the GSI stand, Günter Siegert (left) and Wolfgang von Rüden (centre) of GSI management explain GSI's plans to use heavy ion beams for cancer therapy to Ministerialdirigent Hans C. Eschelbacher.



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On 19 September, friends and colleagues of Maria Fidecaro came to wish her well on her formal retirement from CERN. Left to right - Maurice Jacob, Maria Fidecaro and her husband Giuseppe, who passed a similar career milestone in 1991. Like her husband, Maria continues to maintain a passionate interest in physics.
(Photo GE 21.9.1995)

CERN Courier contributions

The Editor welcomes contributions. These should be sent via electronic mail to courier@cernvm.cern.ch

Plain text (ASCII) is preferred. Illustrations should follow by mail (CERN Courier, 1211 Geneva 23, Switzerland).

Contributors, particularly conference organizers, contemplating lengthy efforts (more than about 500 words) should contact the Editor (by e-mail, or fax +41 22 782 1906) beforehand.

physics sections of the national physical societies of North-West European countries.

Topics include current developments in Theoretical Nuclear Physics, Experimental Nuclear Physics, Applied Nuclear Physics and Detectors and Instrumentation. Special presentations will be given by: J. Barrow (Sussex) - The Early Universe; G. 't Hooft (Utrecht) - Quantum Gravity; and C. Rubbia (CERN, Geneva) - Energy Amplification.

Information from e-mail nwe96@nikhef.nl or World Wide Web http://www.kvi.nl/disk$1/nwe96/nwe96.html

Nobel 1995

Clyde Cowan (left) and Frederick Reines (right) at their original 1953 experiment at the Hanford reactor which saw promising indications of neutrino interactions. (Photo Los Alamos)

The theme of the 1995 Nobel Prize for Physics is leptons, the particles which feel the weak nuclear force, best known in nuclear beta decay. The prestigious award is shared by Frederick Reines of the University of California, Irvine, and by Martin Perl of the Stanford Linear Accelerator Center.

Professor Reines' award is in recognition of his epic 1956 discovery, made with Clyde Cowan at the Savannah River reactor in South Carolina, that the neutrino, predicted by Wolfgang Pauli in 1930, is a physically observable particle. Unfortunately Clyde Cowan died in 1974. Professor Perl's discovery of the tau lepton at the SPEAR electron-positron collider in 1976 was less expected, but no less important for today's Standard Model of particle physics.

The discovery of the neutrino

The discovery of the neutrino is traditionally described as an experimental verification of a bold theoretical prediction by Wolfgang Pauli. However Leon Lederman has pointed out that it should be the experimentalists who get the lion's share of the credit. Experiments provided the data which 'made it perfectly obvious' that Pauli had to invent the neutrino!

Looking at the same data, Niels Bohr was led to suggest that conservation of energy inside the atom would not be absolute.

Pauli only made his suggestion out of desperation, says Lederman, adding 'driving a theorist as good as Pauli to desperation has been the goal of red-blooded experimentalists ever since'.

With beta decay experiments reporting a tiny energy imbalance, Pauli was driven in 1930 to suggest that an otherwise invisible particle was emitted along with an electron when a neutron decayed into a proton. At first, he was reluctant to talk about a particle which could not be detected, but by 1934 the neutrino had been incorporated into Enrico Fermi's theory of weak interactions.

Hans Bethe and Rudolf Peierls calculated the expected absorption rate of neutrinos by nuclei and concluded such particles would be undetectable. However Bethe and Peierls had not known about the enormous numbers of neutrinos emitted in fission reactions.

The initial idea of Reines and Cowan was to catch neutrinos from an underground atomic bomb explosion. Any detector near an exploding bomb would not survive, but perhaps a detector could be dropped down the shaft.Such an experiment was difficult to repeat, and in the immediate post-war years there were powerful new reactors offering alternative sources of neutrinos.

Rather than seeing neutrino emission in beta decay, the aim of Reines and Cowan's detector was to see inverse beta decay, where a neutrino hits a proton, producing a neutron and a positron. The latter would soon annihilate, releasing an electron-positron pair. In addition, Reines and Cowan also wanted to detect the neutron, through the gamma rays emitted in its eventual nuclear capture after it had slowed down. These gamma rays would be seen a few microseconds after the annihilating positron. This 'delayed coincidence' was the key to neutrino discovery.

In 1953, they started work with a 300-litre drum of liquid scintillator at Hanford, Washington, and saw a slight increase in the delayed coincidence signal. This was encouraging, but not enough to claim any discovery.

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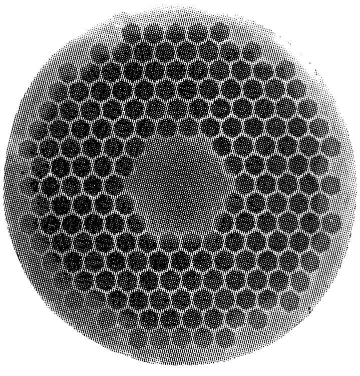

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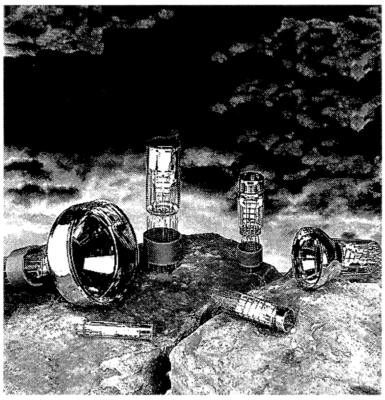

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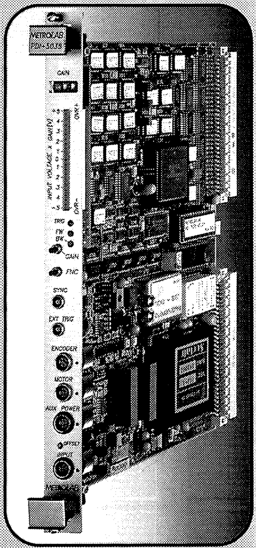

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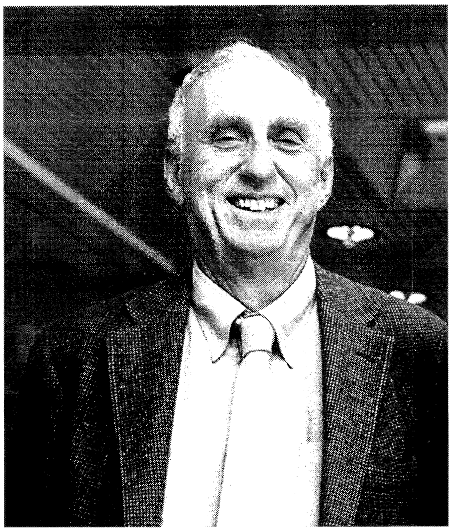

Discoverer of the tau lepton, Martin Perl of the Stanford Linear Accelerator Center shares the 1995 Nobel Physics Prize.

Carolina. Over 100 days of running, they averaged three tell-tale delayed coincidences per hour. Neutrinos were not just symbols in equations. They were for real. On 14 June 1956 Reines and Cowan triumphantly sent a telegram to Pauli in Zurich. Unfortunately the telegram was sent to the University, not the ETH institute where Pauli worked, but the error was dutifully corrected.

More neutrinos

Neutrinos are not only produced in nuclear beta decay. They are also found, with muons, in the weak decays of pions and kaons. Were the neutrinos produced with muons from pion decay identical to those seen in nuclear beta decay?

The question was answered in 1962 by an experiment by Leon Lederman, Mel Schwartz and Jack Steinberger at Brookhaven, which showed that neutrinos come in different kinds. Lederman, Steinberger and Schwartz were awarded the Nobel Prize for Physics in 1988.

The discovery of the tau

In 1974, attention at the SPEAR electron-positron collider at the Stanford Linear Accelerator Center, was focused on the famous J/psi particles. These had been discovered independently by teams led by Burton Richter at SPEAR and by Sam Ting at Brookhaven. These particles had heralded a fourth quark, which carried a special quantum number 'charm'.

Such a fourth quark had been predicted in 1970 by Sheldon Glashow, John Iliopoulos and Luciano Maiani to explain the behaviour of the electrically neutral current of the weak interaction when the quark quantum number called strangeness was involved.

For a while, it looked as though the 'Standard Model' (the term had not yet been invented) of particle physics was complete with four types of quarks grouped as two pairs - up/down and strange/charm - together with two leptons - the electron and the muon, each with its own kind of neutrino.

One of those eager to understand why leptons come in distinct varieties was Martin Perl. Before coming to SLAC, Perl had been Sam Ting's thesis adviser at Michigan. Always on the lookout for signs of new leptons, he did a long search using the two-mile linac, without success. Undeterred, he joined Richter's team at the new SPEAR ring: in his pocket were predictions by J.J. Sakurai and by Y.S. Tsai about what the decays of heavy leptons could look like.

To avoid making it a visible budget item, the 200-metre Stanford Positron-Electron Asymmetric Ring had been built by Richter on a parking lot at SLAC out of the laboratory's operating budget for $5 million in less than two years. By the summer of 1973 it was logging data. One of the experiments lined up for SPEAR was a search for new leptons, but in November 1974 had come the bonanza J/psi discovery and attention focused on getting the most out of SPEAR's Mark I detector.

Earlier, the ADONE electron-positron collider at the Italian Frascati Laboratory and the unconventional CEA Cambridge (Massachusetts) machine had shown how spectacular electron-positron annihilations could be, even at lower energies, producing a surprising number of pions and other hadrons as well as weakly interacting particles. However searches for heavy leptons had been fruitless in the energy region covered by ADONE.

After the J/psi discovery, the SPEAR energy was inched higher in the search for more new particles. Perl noticed a few events which produced an electron and a muon but no other visible particles. At 1975 conferences, Perl was referring to his interesting haul of 24 events as 'U' (for unknown) states.

However most other physicists were obsessed with charm. The J/psi particles, composed of a charmed quark and its antiquark, had only 'hidden' charm. Somewhere there had to be particles with 'open' charm, containing only one charmed quark, and at a mass suspiciously close to Perl's U states. Were Perl's Us due to open charm?

However open charm was soon seen, while Perl, working with Gary Feldman, had accumulated over a hundred events which, he said, defied conventional description. Others were not convinced, alleging the U events to be background noise, spurious effects which mimicked a particle. The mass was suspiciously close to the charm threshold. At the DORIS electron-positron ring at DESY, Hamburg, no U events were seen initially.

Undeterred, Perl kept talking about his Us and was still seeing more them. Boldly he claimed the discovery of a new lepton, the tau, from the initial letter of the Greek word triton - 'third' - weighing in at 1777 MeV, much heavier than the electron at 0.5 MeV and the muon at 105 MeV.

By 1977, independent evidence for the tau came in from the PLUTO detector at the DORIS ring, and by the time of the 1977 Lepton-Photon meeting in Hamburg this had been joined by DASP at DORIS and the DELCO experiment now installed at SPEAR.

Although SPEAR's Mark I detector received several improvements, notably muon shielding to protect the muon signal against hadronic intrusion, the tau was discovered by the same detector which revealed the J/psi. It is probably the first example of separate Nobel Physics Prizes having been earned by the same apparatus.

The Standard Model

If there was a third lepton, then there had to be another pair of quarks. Both were discovered at Fermilab. The fifth quark, beauty, was revealed in 1977, and its partner, top, in 1995. These particles completed today's Standard Model of three quark pairs linked to three leptons and their corresponding neutrinos.

In 1989, the arrival of higher energy electron-positron collisions at Stanford's SLC Linear Collider and CERN's LEP electron-positron collider showed that Nature has no room for more than three kinds of neutrinos, and looking for leptons suddenly dropped out of fashion.

Precision tau physics, probing the third generation of the Standard Model, has become a minor industry at LEP, while precision measurements of the tau mass were made at the Beijing electron-positron collider. The Workshop on Tau Lepton Physics now a major feature in the international physics calendar. Martin Perl is always guest of honour. He has been a member of CERN's Scientific Policy Committee since 1991.

With tau-charm factories planned (October, page 8) tau physics is assured of a bright future.

RESEARCH ASSOCIATE
THEORETICAL PARTICLE PHYSICS
INDIANA UNIVERSITY

Applications are invited for the position of postdoctoral research associate in theoretical particle physics, available September 1, 1996. Initial appointment is for one year, with probable renewal for a second year. We seek outstanding candidates in theoretical particle physics who have overlapping interests with our group. Each application should include a curriculum vitae, a description of research interests and accomplishments, and a list of publications. Candidates should also have at least three letters of reference sent to: Particle Theory Group, Physics Department, Indiana University, Bloomington, IN 47405, USA. Applications received before January 15, 1996 may receive preference. Indiana University is an Equal Opportunity/Affirmative Action Employer.

DESY

Post Doctoral Position

The Deutsche Elektronen-Synchrotron, DESY, in Hamburg, performs basic research in the field of elementary particle physics by means of a High Energy Storage Ring. It is a research institute of international repute which collaborates with similar research centres throughout the world.
Within the program for the advancement of young scientists of the community of major scientific laboratories, we would like to offer a position for a young

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The topics of interest are:
As a study for possible future e+/e- colliders, test accelerators are being constructed and will shortly go into operation. Thus participation in and realisation of technical designs and theoretical analysis in the areas of superconductivity, high frequency and accelerator physics are required.
Applicants should have a Ph.D. in physics or in an allied field and be not more than 32 years old. The contract will be limited to 3 years. The salary will be according to the "MTV Angestellte" Group 11a. Handicapped applicants with equal qualifications will be prefered. DESY is interested in advancing the professional development of women and would encourage women to apply for this position. Written applications complete with certificates and references should be sent to our Personnel Department before 27.11.1995.

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School of Physics and Chemistry

RESEARCH ASSOCIATE POSITION

Applications are invited for a postdoctoral Research Associate Position in the Particle Physics Group. The successful candidate will work in one of the following activities of the group.

1. Studies of electroweak interactions in ALEPH AT LEP at CERN.
2. Deep Inelastic Scattering in the H1 group at HRA at DESY.
3. Detector development for the inner tracking detector for the ATLAS collaboration at the LHC at CERN.
4. BaBar Collaboration at SLAC.

The post is supported by the PPARC in the UK.

For further details and application forms please contact Personnel Services quoting reference number L401, Bowland College, Lancaster University, Lancaster LA1 4YT, UK (Telephone (44) 1524 846549). Application forms should be returned to Personnel by 10 December 1995.

Further information about this post can be obtained from Professor T. Sloan
(e-mail T.Sloan@Lancaster.ac.uk).

The University of Lancaster is an equal opportunity employer.

Assistant Research Astrophysicist

Center for Particle Astrophysics

UNIVERSITY OF CALIFORNIA AT BERKELEY

The Center for Particle Astrophysics, an NSF Science and Technology Center, invites applications for the position of Center Fellow.

The Center is investigating the dark matter problem through four lines of experimental attack: using conventional and cryogenic detectors to detect the interaction of dark matter particles in the laboratory; studying the diffuse radiation from the early universe (particularly the 3K microwave background); using distant supernovae to determine how much dark matter exists; and studying the role of dark matter in the evolution of large-scale structure. The Center Fellowship is intended to provide a young experimentalist with the opportunity to bring fresh insight (particularly from other fields of physics) to bear on the dark matter problem and take a leading role in developing new initiatives. This two-year position will start in October, 1996, with a possible extension for a third year.

Candidates should have a Ph.D. in Physics of Astronomy. Research experience at the post-doctoral level is preferred. Salary will be commensurate with experience. Interested applicants should submit a statement of their research interests, a curriculum vitae, and arrange for letters of support from three referees who are familiar with their work. These items and a letter of application should be sent to:

Professor Bernard Sadoulet
Center for Particle Astrophysics
301 LeConte Hall
University of California
Berkeley, CA 94720, USA

The closing date for applications will be January 1, 1996. The University of California is an Affirmative Action/Equal Opportunity Employer. We especially encourage applications from female and minority candidates.

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The Swedish Natural Science Research Council now expands these activities by inviting applications for a tenure track type Council Researcher position at the assistant/associate professor level. Initially the position is for 3+3 years. The successful applicant is expected to join one of the Swedish research groups. The salary range will correspond to that of an associate professor (SEK 255 000-350 000 per year, i e USD 36 000-49 000 per year).

Applications should include a detailed curriculum vitae and bibliography, summary of past research, a short research plan, names of three references who can be contacted and, at most, 10 scientific papers. The applicant is kindly asked to state which Swedish research group he/she would like to join. *Four* copies of the application and reprints, also in quadruplicate, should reach the Swedish Natural Science Research Council, Box 7142, S-103 87 Stockholm, Sweden, by December 1, 1995.

Further information can be obtained from Ms Natalie Lunin, at the Secretariat of NFR, Telephone: +46-8-454 42 32, fax: +46-8-454 42 50, or email: finn@nfr.se

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RESEARCH ASSOCIATE

Experimental High Energy Physics

The Department of Physics at Stanford University is inviting applications for a postdoctoral research associate to participate in a rare K^0 decay experiment at Brookhaven National Laboratory and in a long baseline neutrino experiment, MINOS, at Fermilab.

The K^0 decay experiment, BNL E871, looks for rare decay modes with a single event sensitivity of 10^{-12}. The emphasis is on two body decays, $\mu^+\mu^-$, e^+e^- and $\mu^\pm e^\mp$. Initial five month long data taking run was concluded in June 1995 and has met its planned goals. It is expected that the experiment will run again starting in February 1996 and possibly also in 1997.

The MINOS experiment is designed to be sensitive to $\nu_\mu \to \nu_e$ and $\nu_\mu \to \nu_\tau$ oscillations down to $\sin^2 2\theta = 0{,}01$ and to Δm^2 values below 10^{-2}. This experiment was recently endorsed by HEPAP as an important element of the future US high energy physics program. The neutrino beam will be produced by the protons extracted from the Fermilab Main Injector, currently under construction and scheduled to be completed by 1999. The far detector will be a multi-kiloton magnetic spectrometer in the Soudan mine in Minnesota, some 730 km away. The existing Soudan 2 detector will also form part of the detector apparatus. It is hoped that data taking can begin in 2001.

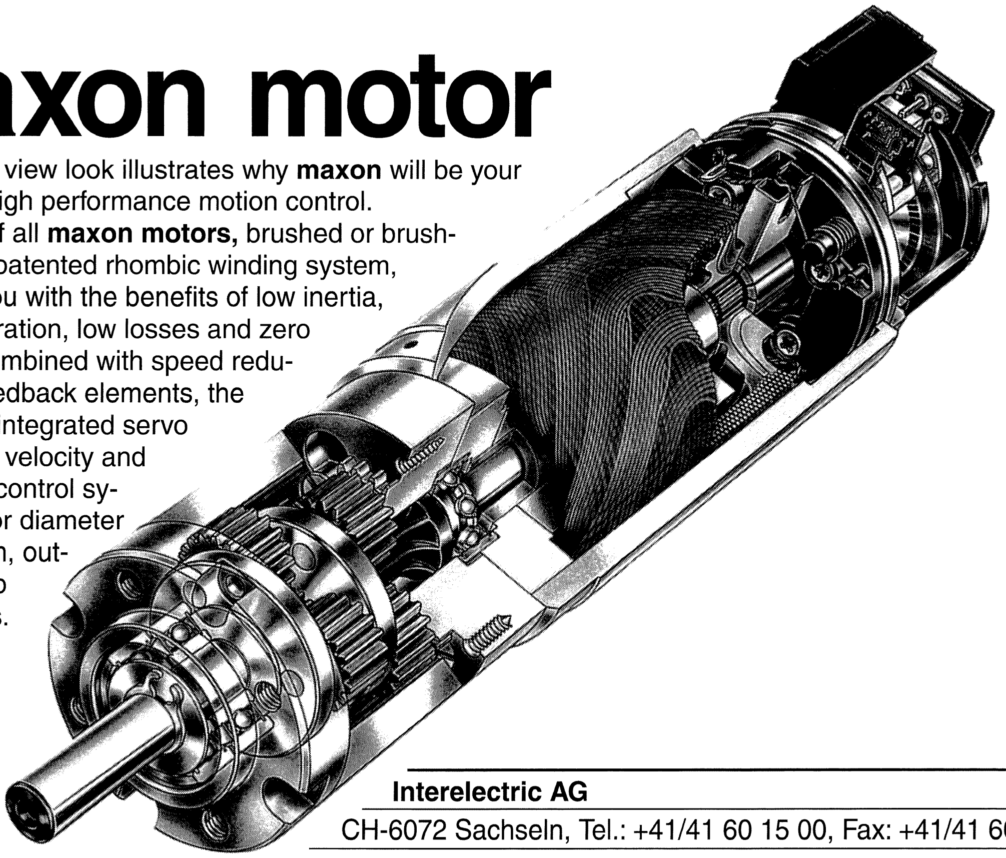
The successful applicant will be expected to spend the first year at BNL, participating in E871 data taking and MINOS test beam work. Subsequently it is anticipated that the majority of his or her time will be spent in residence at Stanford, working mainly on MINOS simulation, design, and construction but also participating in the analysis of E871. The initial appointment will be for three years with the possibility of an extension.

Interested applicants are requested to send three letters of reference and a resumé to:

Professor Stanley Wojcicki
SLAC
PO Box 4349, MS 63
Stanford, CA 94309, USA

The applications will be accepted until December 15, 1995 or until the position is filled.

Stanford University is an equal opportunity, affirmative action employer. We are especially interested in receiving applications from female and minority physicists.



POST DOCTORAL RESEARCH ASSOCIATE

CEBAF High Resolution Spectrometer Group (Hall A)

The Continuous Electron Beam Accelerator Facility (CEBAF), located in Newport News, Virginia, USA, is a world class facility for nuclear physics research. With a 4 GeV high intensity, continuous wave electron accelerator, CEBAF will explore the fundamental nature of nuclear matter with particular emphasis on quark-gluon degrees of freedom. The physics program of the High Resolution Spectrometer Group focuses on precision studies of electromagnetic and weak-neutral current form factors of the nucleon and bound nucleon properties in few body systems. The experimental equipment in Hall A, namely, a pair of identical 4 GeV/c High Resolution Spectrometers equipped with a focal plane polarimeter, are expected to be operational in 1996.

Applications are being invited for a post-doctoral research associate position for the High Resolution Spectrometer Group. The position requires a recent Ph.D. in Experimental Subatomic Physics. The successful candidate will participate in the commissioning of the experimental equipment in Hall A and analyze initial experiments. Demonstrated experience in the implementation and analysis of lepton-nucleus physics experiments is preferred. Interested candidates should send curriculum vitae and three letters of reference to: CEBAF, ATTN: Employment Manager, 12000 Jefferson Avenue, Newport News, Virginia 23606, USA. Please specify position #PT2104 and job title when applying. CEBAF is an equal opportunity, affirmative action employer.

POSTDOCTORAL POSITION
EXPERIMENTAL HIGH ENERGY PHYSICS
University of California, San Diego

The Department of Physics at the University of California, San Diego invites applications from outstanding candidates for a Postdoctoral Researcher position to work in the field of Experimental High Energy Physics.

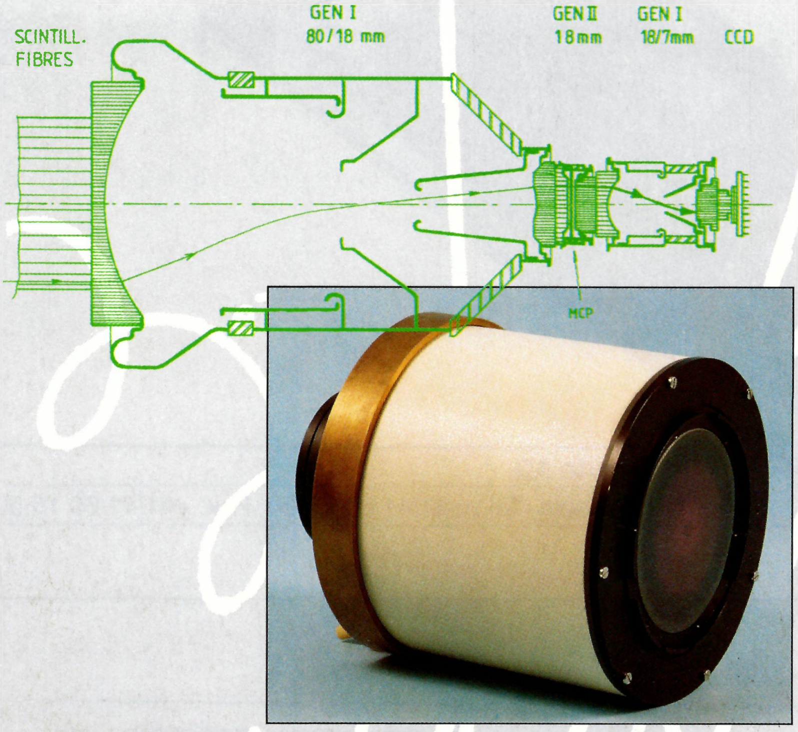
UCSD is a member of the CLEO Collaboration at the Cornell Electron Storage Ring and is committed to a strong b-physics program with the CLEO detector. The CLEO detector has recently been equipped with a three layer, three-dimensional Silicon Vertex Detector to significantly enhance its charged particle tracking capability. The successful candidate is expected to play a major role in the commissioning of the silicon detector and in the integration of the silicon detector data with that from pre-existing tracking devices. The candidate is also expected to play a leading role in physics analysis using data obtained with this upgraded detector. To this end, the candidate's prior experience with charged particle tracking in general and silicon vertex detectors in particular shall be very useful.

For reasons of efficiency, the selected candidate shall be posted onsite at Cornell University in Ithaca, New York. The salary is commensurate with the candidate's qualifications and will be based on the University of California pay scale.

Interested candidates should send a copy of their CV, three letters of recommendation and a statement of physics interests to: **Prof. Vivek Sharma, Physics Department 0319, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0319, USA. Email: vsharma@ucsd.edu.**

The deadline for applications is **1 December 1995.**

In compliance with the Immigration Reform and Control Act of 1986, individuals offered employment by the University of California will be required to show documentation to prove identity and authorization to work in the United States before hiring can occur. The University of California is an Equal Opportunity/Affirmative Action Employer.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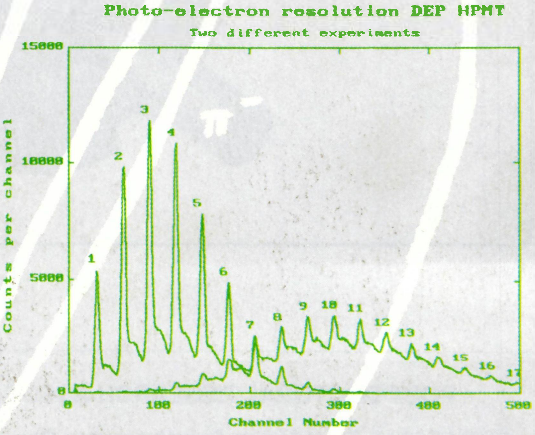
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